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BIOMETRIKA

A JOURNAL FOR THE STATISTICAL STUDY OF BIOLOGICAL PROBLEMS

23

EDITED
IN CONSULTATION WITH FRANCIS GALTON
BY
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AND
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VOLUME III
JANUARY 1904 TO DECEMBER 1904

CAMBRIDGE
AT THE UNIVERSITY PRESS

LONDON: C. J. CLAY AND SONS, AVE MARIA LANE
AND H. K. LEWIS, GOWER STREET
NEW YORK: THE MACMILLAN COMPANY
LEIPSIC: BROCKHAUS
BOMBAY AND CALCUTTA: MACMILLAN AND CO., LIMITED

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190785

Cambridge:
PRINTED BY J. AND C. F. CLAY,
AT THE UNIVERSITY PRESS.

574.0542
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VOLUME III JANUARY, 1904 No. 1

BIOMETRIKA.

ON THE RESULT OF CROSSING JAPANESE WALTZING WITH ALBINO MICE.

BY A. D. DARBISHIRE, Balliol College, Oxford.

THE object for which the following experiments were undertaken was to test the validity of Mendel's Principles of Heredity, which have recently acquired considerable importance, by becoming intimately involved in the question of the origin of species. The term Mendelian Principles is used in its widest sense, to include not merely the simple Mendelian phenomena of Dominance or Segregation, but the much more fundamental doctrine of gametic purity.

METHOD OF DESCRIPTION.

The method of description employed in this paper is the same as that used in the three reports on these experiments which have already appeared: the mice are classified, according to the relative extent of the coloured patches on a white ground, into six groups.

Group 1 (Fig. 1) has more white and less extent of coloured patches than the normal waltzing mouse. The distribution of colour on a waltzer is shown in Fig. 6.

I wish to draw special attention to the existence of this group, because Castle*, who quoted my second paper for another purpose, denies that any mice with less colour than a waltzer had occurred in my experiments

Group 2 (Fig. 2) has about as much white as a normal waltzing mouse.

Group 3 (Fig. 3) has less white (i.e. greater extent of coloured patches) than a waltzer.

Group 4 (Fig. 4) has still less white, and leads on to

Group 5 (Fig. 5) which has no pure white, but the belly is whitish, not grey.

Group 6 contains mice whose bellies are nearly the same colours as their backs.

---

* "Mendel's Law of Heredity," *Proc. American Academy*, Jan. 1903, pp. 533—48.

The individuals of each group can also be classified according to the colour of the coloured patches.

Class a = yellow.

Class b = fawn yellow.

Class c = pale wild colour
Class d = dark wild colour } , i.e. that of the house-mouse.

Class e = black.

Class f = "lilac" = pale blue grey; at present only exhibited by the offspring of hybrids.

Class g = chocolate.

The letter "p" after a mouse indicates that it has a pink eye, the letter "W" that it waltzes; to take two examples, $2b\,(pW)$ is a waltzer, $6d$ or $6c$ is a house-mouse.

I propose to defer a detailed discussion of the nature of these categories to a later date: but I hope the foregoing remarks will leave no doubt in the reader's mind as to what is meant by each class; in fact, all the classes except the first two explain themselves. I am sorry the word fawn was used in my second paper, because it is used to denote both a and b by mouse fanciers; a is simply a yellow colour; b is yellow, with, in many cases, black in it; at any rate, there are intermediate stages linking b with c (i.e. pale wild), whereas a is not so linked with c except through b.

In cases of intermediate colours the mice are entered $5bc$ and so forth: a minute discussion of the skins (which are kept) is deferred.

METHODS OF REGISTERING.

The method of keeping, registering and cataloguing which I now pursue has gradually grown up of itself in the course of a year rather as a result of necessity than by deliberate invention on my part. Lack of a proper method of registering at the beginning of the experiments rendered many of the dealings with mice a matter of great difficulty; and I suggest that if the reader is taking up work of this kind he will not suffer from a similar inconvenience if he adopts a method similar in principle to that which I am about to describe.

During the latter part of the experiment there were some fifteen hundred mice in the room set apart for the purpose; and it was quite a simple matter to look up in the catalogue book any mouse in the room, and *vice versâ*, to find in the room a mouse of any given ancestry. The method is very simple, and was based on a system of cross-reference, which enabled one to refer (as already stated) from the books to the mice, and from the mice to the books.

The following account, then, will be of little if any interest to the reader who does not intend to do similar work.

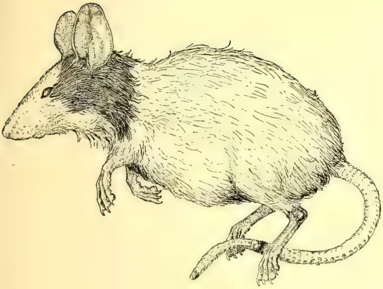


Fig. 1.

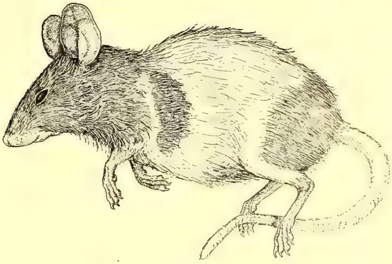
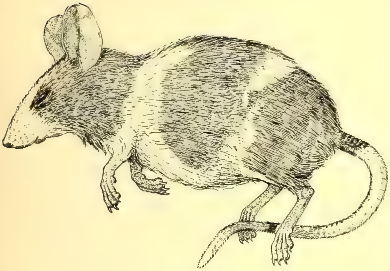


Fig. 2.



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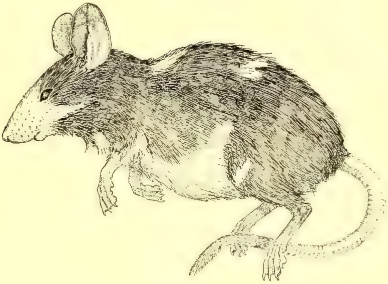


Fig. 4.

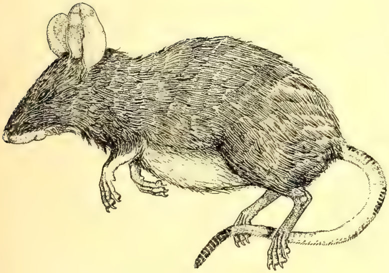


Fig. 5.

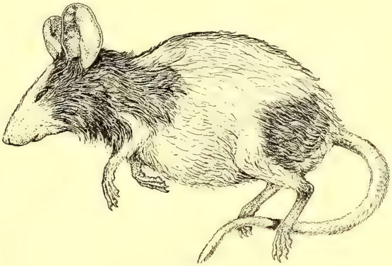


Fig. 6.

Let us imagine that our object is to make crosses between albino and Japanese waltzing mice, and that we are provided with a stock of waltzing mice which we know to breed true, and of albino mice of authentic pedigree. Two sorts of books are necessary—(i) a book recording the matings, and later on (ii) an illustrated catalogue. The entry of the cross in the mating book is quite simple. The date underneath the description refers to the day on which the mice were put together; and the occurrences which come to pass on the subsequent dates are also recorded.

Cross 1.

♀ Albino (pure bred) from Mr Steer.
♂ Japanese waltzer.

Dec. 24.

♂ removed, Jan. 10th.
8 young born, Jan. 16th.
♀ removed, Feb. 8th.
Young sexed, Feb. 25th.

The offspring are catalogued in two places for reasons which will shortly be explained: first they are catalogued as soon as the colour of their eyes and coat is discernible; this might quite well be done in the mating book; but I find it more convenient to have a separate book (First Catalogue) for the purpose: the coat-colour and eye-colour of each mouse are entered directly they can be plainly seen, so that a minimum number of records is lost through cannibalism or disease: nothing else is recorded; the sex is not (for it cannot be) determined. Such an entry appears as follows:—

Cross 1. 5*c*, 5*c*, 5*c*, 3*c*, 2*c*, 2*c*, 1*c* (ix. 21).

The entry in brackets gives the date on which the mice were catalogued; if this is not done and a note is made in the mating book that a young one of a certain description has escaped or died, doubt would arise in the mind of the observer as to whether that mouse had been catalogued or not.

When the young are sexed they are entered in the illustrated catalogue, which, beside the record of matings (already described), is the second kind of book necessary for the observations. In this book each mouse is given a name: thus the first mouse which happens to be described, in the litter of the imaginary cross which we entered in the mating book above, is $1^{a\,i}$, the second $1^{a\,ii}$, and so on. The "a" signifies that the individual belonged to the first litter produced by those parents; individuals of the second litter produced by the same parents would receive the names $1^{b\,i}$, $1^{b\,ii}$, $1^{b\,iii}$, etc. Roman numerals are used to indicate the individuals of the family because they are never likely to become too large to be convenient, for litters very rarely exceed, and, in fact, very seldom attain, the number of ten, and $1^{a\,x}$ is quite convenient to write. In cases of albinos and self-coloured mice, in which the tail is uniformly covered with pigment, I have merely written the description of the mouse, as a picture of such a one would be superfluous: but in all cases of piebald mice I have made a drawing of the animal as seen from the right, left, and dorsal aspects by painting the colour-pattern on outline drawings of mice (printed for me by Messrs Palmer and Howe of Manchester) kept for the purpose; and in cases of completely coloured mice with incompletely coloured tails I have merely drawn one view to show the arrangement of colour on the tail. All mice, which have reached the age at which they are sexed, have been described in this manner.

Now suppose that one wants to pair these hybrids (First Crosses) together; one proceeds in this way.

Another mating book has to be used to enter the matings of the hybrids (to avoid hopeless confusion); and the numeral which indicates a cross or pair is preceded by some letter (such as *H*) to distinguish it from the same number which refers to a cross between a waltzing mouse and albino. I have called these pairs or crosses H_1 H_2, etc. The individuals paired are entered thus in the mating book:

H_1
♀ $7^{a\,iii}$
♂ $1^{a\,i}$ *March* 9.

Against $7^{a\,iii}$ in the illustrated catalogue book H_1 is written, so that one is enabled to refer from the ancestry of a mouse to its place in the room (for of course all pairs of the same kind, i.e. *H*'s for example, are kept together). Whenever $7^{a\,iii}$ is mated again to form another pair or cross, the number of each successive pair in which it is concerned is put after it, so that if one wants to find $7^{a\,iii}$ one looks at the last number against its name in the mating book.

The value of the illustrated catalogue lies in the fact that in many families the brothers and sisters are so unlike that when they are again looked up reference to the catalogue will convince one that one is dealing with the right mouse: of course they are identified by the number on their cage, so that their picture is not a necessary means of identification, but it is an additional safeguard against error.

Fig. 7 represents a sample page of the illustrated catalogue on a reduced scale.

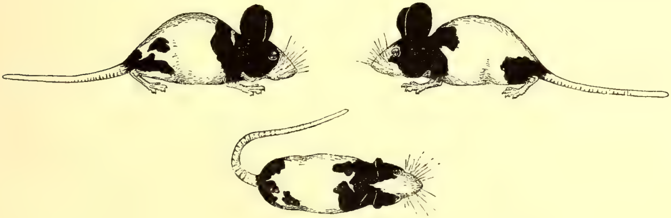


Fig. 7.

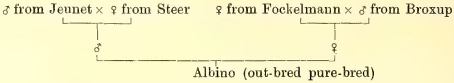
DESCRIPTION OF PARENTS.

Japanese Waltzing Mice.

These animals are distinguished from ordinary (say albino) fancy mice by their smaller size, by their extreme liability to disease, but especially by their curious habit of spinning round, by the ceaseless movement of their heads, and by the retrograde motion of the body when not waltzing. The mice used by me had pink eyes, and bore patches on the body of colour indicated by b: the range of variability in colour was practically nothing; that of the extent of the coloured patch was small: accurate pictures have not been kept of all of them because the simple Mendelian statements, which it was the original object of the experiment to test, did not lead to the expectation that minute study of these mice would be necessary; the exact distribution of the colour on the waltzing parent is therefore not known in all cases; in those cases in which pictures of the waltzers were made, a classification of them has been made into (α) waltzers with less colour than Fig. 7, and (β) waltzers with more colour than Fig. 7. All the waltzers used were of pure strain.

Albino Mice.

In the previous experiments of this kind (conducted by von Guaita) the albinos used were of uniform ancestry, being in-bred for 29 generations; that is, they were also pure-bred. I obtained my albino stock chiefly from Mr Steer in England, from M. Jeunet in Paris, and from Herr Fockelmann in Hamburg. From the pure-bred mice which I got from Mr Steer I raised in-bred pure-bred albinos, and by mating the foreign mice with English ones I obtained out-bred pure-bred mice. An out-bred pure-bred mouse would have this ancestry for example:


♂ from Jeunet × ♀ from Steer
♀ from Fockelmann × ♂ from Broxup
♂
♀
Albino (out-bred pure-bred)

Out-bred cross-bred mice were obtained by crossing black or yellow mice with albinos—in-bred cross-bred were obtained by waiting for a litter, from such a cross, in which there were both albinos and blacks (or yellows), then pairing a black mouse with his white sister, and so on for many generations.

A list of all the mice bred during the experiment is given in Appendix I., Tables A to H.

THE HYBRIDS.

Before describing the results of crossing albinos and Japanese waltzers, I think it is advisable to define clearly the terms which I shall use to describe each generation. The offspring produced by crossing a Japanese waltzer with an albino I propose to call the hybrid, simply; the offspring of these hybrids paired together, children of hybrids; the offspring of the hybrids crossed with albinos, children of hybrids and albino. These terms are perfectly simple, but it is impossible to be too explicit about terms such as these.

The hybrids are invariably dark-eyed; their coat is never completely white, and they never waltz; the two facts about them which strike one immediately are (i) that whereas the parents are all like the other members of their race, the hybrids are by no means all alike; they exhibit much variability in coat-colour and in the distribution of their colour; (ii) that not only do they differ among themselves, but they are absolutely different from either parent; the character of neither parent can be said to be dominant over the other in the sense that it exists in the hybrid to the exclusion of the other, which is what Mendel meant by dominance. To make up, however, for this deficiency in dominance, the characters of both parents are recessive, in so far that neither of them appear in the hybrid. This is plainly not a case of simple Mendelian dominance, though I am perfectly ready to admit that it may be an instance of the mysterious properties of heterozygotes, confessing at the same time that I do not see how the admission of this fact helps. It seems to me that we have not got any further in this direction than Darwin had when he called phenomena of this kind reversions to ancestral condition.

The eye-colour and the amount and nature of coat-colour are not the only new characters which appear in the hybrids: there is a correlation between the size of the patches of colour and the intensity of the colour in such a way that the lighter the colour the more space it occupies. The measure of this correlation is between $-0{\cdot}2$ and $-0{\cdot}3$. This character of the hybrids is clearly absent in the parents; for, while the waltzers vary slightly in the amount of colour which they possess, the colour itself does not vary: the albinos have no colour at all*.

We have up to now merely stated the fact that the hybrids are variable; it remains to try to account for this variability. How Mendelians will account for it I do not know, but I have facts to show that it is due to ancestry of the parent forms.

Fraternal correlation.

From the Mendelian point of view the families should be all similar; and this would lead to fraternal correlation $=0$. Fraternal correlations are, however, remarkably like those observed in fraternities which are not cross-bred; taking either the colour of the coat or the extent of the white patches as the character to be examined, we find a fraternal correlation very nearly equal to 0·5. This shows that there is (1) a sensible range of variation within each family, and (2) a considerable range in the mean characters of different families. The variation within the family seems to me incompatible with any Mendelian hypothesis which does not involve a complexity in the constitution of the waltzing parent, leading to the assumption that its coat-colour depends not on one allelomorph, but on a number. This might be conceivable, but it would involve a reduction in the proportion of albino young among children of hybrids incompatible with that observed in the next generation.

---

* The obvious want of "normality" in the distribution of coat-colour and of whiteness in all the generations observed renders the determination of the correlation coefficients very difficult. The process adopted, which is due to Professor Pearson, will be explained and justified in a future paper by him.

We see therefore that characters of hybrids are not compatible with, still less explained by, Mendelian principles; it still remains to account for them.

Parental correlation.

If we classify the hybrids into those in which the albino parent was pure-bred, and those in which it was cross-bred, i.e. in which it had some pigmented ancestors, and determine the correlation between the colour of the young and the purity of the albino parent, we find that it is about $-0·15$, and the correlation between the amount of whiteness in the hybrids and purity of albino parent about $-0·2$. These are quite sensible correlations; they show that there is a distinct relation between the pigmentation of the hybrids and of the ancestors of their albino parent: they show therefore that the albino cannot be said to be gametically pure in respect of its whiteness, but that in order to predict the character of its young a knowledge of its ancestry is necessary. The character of the hybrids is therefore influenced by the ancestry of the albino parent: but it is also affected by the character of the waltzing parent. As has already been stated, pictures of all the waltzing parents of hybrids have not been made, but the waltzing parents of 210 out of the 340 hybrids obtained are represented by accurate diagrams, and these have been divided into (α) those with less extent of coloured fur than the mouse figured in Fig. 1, and (β) those with more; from waltzers of category (α) 113 young have been produced; and from (β) 97. The coat-colour and degree of whiteness in these young is shown in Tables IV. and V. (page 38). It will be seen that there is considerable correlation between the amount of white in the waltzing parent and that in the resultant hybrid. Table V. shows the correlation between coat-colour of hybrids and whiteness in their waltzing parent. In both these characters the coefficient of parental correlation is very nearly $\frac{1}{3}$.

The amount and nature of the colour of a hybrid are therefore not constant, but exhibit great variability. (a) The hybrid does not show dominance of the character of either parent, and (b) its variability is sensibly correlated, not only with the actual character of the "dominant" parent, but also with the character of the ancestry of the "recessive" albino parent. Whatever theory these facts are to be reconciled with, I maintain that it is *not* with the theory of gametic purity. How far they are reconcilable with other theories of heredity is a more difficult question.

In order to find out whether the results obtained are in accordance with the law of ancestral inheritance, as stated by Pearson (cf. *Biometrika,* Vol. II. pp. 211–229), it would be necessary to examine more closely than is here possible the effect produced upon all the coefficients of parental, grandparental, and other ancestral correlation, and upon the paternal correlation by the rigid selection of parents which has taken place in this as in all other hybridising experiments. These results are extremely complex, and cannot be predicted without long and difficult enquiry; some of them have, however, been examined by Pearson ("Mathematical Contributions to the Theory of Evolution," *Phil. Trans.*, Vol. 200 A, 1902), who shows that "sexual and natural selection can sensibly modify the intensity of inheritance as measured by the coefficient of correlation; the former tends to raise, the latter to lower its intensity" (p. 43).

The original statement embodied by Galton and Pearson in the Law of Ancestral Heredity relates to a population in which two conditions hold, namely, (i) all mating is at random; in other words the correlation between the characters of male and female mates in any generation is 0, and (ii) all the individuals in the generation have an equal chance of producing young. Now it is a fact, which is often forgotten, and on which I wish to lay great emphasis, that in the experiments described, and in all cases where two races or breeds are systematically crossed, the first of these conditions is deliberately destroyed, and a process of assortative mating is performed, such that the coefficient of correlation between parents is given the value -1 instead of zero. Thus, in the present case, if we know that the father of the hybrid is an albino, we may certainly infer that the mother is not, and *vice versâ*. The effect of this perfect negative correlation between the parents must be to reduce the coefficient of correlation between parents and offspring to 0 (i.e. to destroy the correlation altogether) in every case in which the results of reciprocal crosses are identical.

This may be readily seen by a simple illustration: if we call waltzers with more colour β, and with less a, and the albino parents A, and if we write the female first, the possible unions are:

$$aA,$$
$$\beta A,$$
$$Aa,$$
$$A\beta.$$

And if reciprocal crosses produce the same results, the offspring of aA and Aa will be identical, as will those of βA and $A\beta$. Now suppose that the pairs aA or Aa each produce a offspring of one kind, b of a second kind, while the pairs βA or $A\beta$ produce c young of the first kind and d of the second: if we make a table of the correlation between (say) maternal character and character of young, it will have the form:

Young.

	1	*2*	Totals
a or β	$a+c$	$b+d$	$(a+b+c+d)$
A	$a+c$	$b+d$	$(a+b+c+d)$
Totals	$2(a+c)$	$2(b+d)$	$2(a+b+c+d)$

And since every measure of association or correlation becomes zero with the difference of the products of diagonally opposite squares of such a table, we see that whatever measure be adopted must in this case give a value $= 0$, since the difference of the cross products $= (a + c)(b + d) - (a + c)(b + d) = 0$.

It is of course evident that this important result is a necessary arithmetical consequence of the way in which the parents have been mated and of the identity between reciprocal crosses; it does not depend on any theory of the nature of inheritance, and it involves no statement about the mean character of the young produced; the young may be intermediate between their two parents, or exactly like one or the other, or wholly unlike both.

A further effect of breeding experiments, which involve sudden (and generally great) changes in the correlations between male and female, is a condition of instability during the first few generations. A race may become stable with any constant amount of assortative mating, but a sudden change results in a condition of instability, making it peculiarly difficult to discuss those first generations which are too often the only experimental data available.

These considerations, usually forgotten by those who criticise the law of ancestral inheritance, must be carefully borne in mind by anyone who wishes to realise the questions actually at issue.

We have seen that a process of crossing, such as that performed with the mice described, involves a total absence of correlation between parents of either sex and offspring if the individuals of either race are chosen with equal frequency as male and as female parents. It must be pointed out that many of the tables which accompany this paper are not tables showing correlation between all parents of one *sex* and their offspring; but tables of correlation between all parents of one *character*, whatever their sex, and their young.

An examination of the full list of hybrids given in Table A, Appendix I., will show that the results of reciprocal crosses are so nearly identical as to justify the neglect of sex in the treatment of the data: a table of the correlation between the coloured waltzing mice or the albino mice and their hybrid young such as any of the Tables IV.—VII., may therefore be considered to give approximately the same result as if each referred to half the whole crosses from random unions between waltzing mice and albinos—that half namely in which all the parents are of one sex.

Such a way of regarding the tables is at best only an approximation to the truth; a fuller discussion of the parental and indeed of all correlations observed during the experiments must be published later: in the meantime the present way of regarding them may be useful as a preliminary test of their compatibility with the law of ancestral inheritance.

On the view suggested Tables VI. and VII. may be regarded as showing the result of two operations; it may be considered that first one parent has been rigidly selected and that secondly the coefficient of assortative mating between this parent and the other has been made equal to -1. By this supposition we are enabled to apply a formula provided by Pearson (*Phil. Trans.* Vol. 200 A, 1902, pp. 39—40).

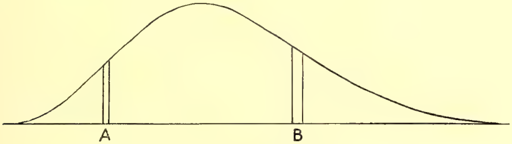


Fig. 8.

If we could make a diagram showing the frequency of any character, coat-colour or other, among mice in general, we may assume that the result would be something like Fig. 8; and the albino mice would be represented in relative frequency and position by one small strip (say A) of such a diagram, the waltzing mice by another small strip (say B).

Before the experiment began each set of mice, albinos and waltzers, formed a separate community, the individuals mating together, either at random or not, and having a standard deviation different from that of mice in general; the assortative mating within these groups we may call r_{12}; and let us call the ratio between the standard deviation of albinos and that of mice in general μ_1, the ratio between that of waltzers and that of mice in general μ_2.

Now calling r_{13}, r_{23} the coefficients of correlation between normal male and female mice and their young, and calling σ_3 the standard deviation of filial mice in general resulting from unselected unions, we have to find the relations between these quantities and Σ_3, R_{13}, the standard deviation and parental correlation of the filial mice resulting from a cross, in which assortative mating has been carried so far that the coefficient of correlation between parents, which we will call ρ_{12}, is equal to -1.

In the memoir quoted, Pearson has shown* that these quantities are connected by the following relations:

Writing for brevity

$$\beta_{13} = \frac{r_{13} - r_{23} r_{12}}{1 - r_{12}^2}$$

and

$$\beta_{23} = \frac{r_{23} - r_{13} r_{12}}{1 - r_{12}^2},$$

---

* Pearson's investigation is not strictly applicable to the present case, because he does not consider the long-continued selection of parents in past generations involved in the statement that the races used are pure.

we have

$$\Sigma_3^2 = \sigma_3^2 \{1 - \beta_{13}^2 (1 - \mu_1^2) - \beta_{23}^2 (1 - \mu_2^2) - 2 (r_{12} - \beta_{12} \mu_1 \mu_2) \beta_2 \beta_3\},$$

$$\Sigma_3 R_{13} = \sigma_3 \{r_{13} - (1 - \mu_1) \beta_{13} - (r_{12} - \rho_{12} \mu_2) \beta_{23}\}.$$

Now we are proceeding on the assumption that in the experiments under discussion the two coefficients of parental correlation r_{13} and r_{23} are equal; we may therefore suppress their suffixes and write each $= r$; further, we may express the purity of the original races used by writing for each of them r_{12}, the coefficient of assortative mating, $= 1$.

We have then

$$\beta_{23} = \beta_{13} = \frac{r (1 - r_{12})}{1 - r_{12}^2} = \frac{r}{1 + r_{12}} = \frac{r}{2};$$

and our formulae become

$$\Sigma_3^2 = \sigma_3^2 \left\{1 - \frac{r^2}{4} (1 - \mu_1^2) - \frac{r^2}{4} (1 - \mu_2^2) - \frac{2r^2}{4} (1 - \rho_{12} \mu_1 \mu_2)\right\}$$

and

$$\Sigma_3 R_{13} = \sigma_3 \left\{r - \frac{r (1 - \mu_1)}{2} - \frac{r (1 - \rho_{12} \mu_2)}{2}\right\}$$

$$= \sigma_3 \left\{\frac{r\mu_1}{2} + \frac{r\rho_{12} \mu_2}{2}\right\}.$$

Now suppose the suffix 1 to denote the parent whose correlations we are investigating and let us first examine the waltzing parent, so that the suffix 2 denotes an albino; we may fairly say that the ratio of the standard deviation of coat-colour among albinos to that of mice in general $= 0$, and we have for R_{13} the correlation between waltzing mice and their hybrid offspring,

$$R_{13} = \frac{\frac{r\mu_1}{2}}{\sqrt{1 - \frac{r^2}{4} (1 - \mu_1^2) - \frac{r^2}{4} - \frac{2r^2}{4}}},$$

$$R_{13} = \frac{\frac{r\mu_1}{2}}{\sqrt{1 - r^2 + \frac{r^2 \mu_1^2}{4}}},$$

and we see that the value to be expected depends (i) on the correlations between parent and offspring in those simpler cases of random mating first dealt with by Galton and Pearson in the Law of Ancestral Heredity, and (ii) on μ_1, the ratio between the standard deviation of the selected race of waltzing mice and that of the general population from which they are descended. We have no means of evaluating μ_1 in the case of coat-colour, but we know that it is small. We may fairly assume for r the value so often found by Pearson and his pupils, and we will therefore write $r=\frac{1}{2}$; so that we have

$$R_{13}=\frac{\frac{1}{4}\mu_1}{\sqrt{\frac{3}{4}+\frac{\mu_1^2}{16}}},$$

which may clearly take a great number of values according to the value of μ_1 ranging from 0 when $\mu_1=0$ to 1 when $\mu_1=\infty$.

We have found the correlation between a variable group of selected parents, the mates being invariable. To find the correlation between these invariable mates and their offspring we must write $\mu_1=0$; and we have, remembering that $\rho_{12}=-1$,

$$\Sigma_3 R_{13}=\sigma_3\left\{r-\frac{r}{2}-\frac{r}{2}+\frac{r}{2}\rho_{12}\mu_2\right\},$$

or

$$\Sigma_3 R_{13}=\sigma_3\left\{\frac{r\rho_{12}\mu_2}{2}\right\}=-\frac{\sigma_3 r\mu_2}{2},$$

and

$$\Sigma_3^2=\sigma_3^2\left\{1-r^2+\frac{r^2\mu_2^2}{4}\right\},$$

or

$$R_{13}=\frac{-\frac{1}{2}r\mu_2}{\sqrt{1-r^2+\frac{r^2\mu_2^2}{4}}};$$

and writing $r=\frac{1}{2}$, we have

$$R_{13}=\frac{-\frac{\mu_2}{4}}{\sqrt{\frac{3}{4}+\frac{\mu_2^2}{16}}}.$$

In the attempt to determine correlation between the invariable coat-colour of an albino mouse and the colour of its young, we meet with the difficulty that the correlation coefficient takes the indefinite form $\frac{0}{0}$, and cannot therefore be directly evaluated. The only character of an albino connected with its colour which can be evaluated is ancestral purity or impurity, that is the absence or presence of pigmented individuals in its ancestry; and if the albinos be classified into pure and impure it is found that the correlation between the presence of pigment in their ancestry and the amount of whiteness or the depth of colour in their hybrid children is *invariably negative* (cf. Tables VI. and VII.). On any theory of gametic purity the correlations should of course be zero; they are in fact of quite significant magnitude, and considering the probable error of the method adopted they are not unlike. The values obtained are:

Between purity of albino parent and

(*a*) Amount of white coat in hybrid – 0·21
(*b*) Colour of coat . . . . – 0·16

the differences being well within the probable error of the method.

It is not suggested that the remarks here offered prove an agreement between the results obtained and those which follow from the law of ancestral heredity. It is contended that the experiment confirms a result, already obtained by Cuénot, that the ancestry of albinos is a factor in determining the characters of the young produced when albino and coloured mice are crossed; it is contended that this result makes it impossible to regard albinism as a character which is transmitted in a state of "gametic purity" by every individual which exhibits it; and therefore since the ancestry of albinos has to be taken into account in predicting their behaviour when crossed, some law of ancestral heredity must be formulated. The present data do not enable us to determine the correlations between parent and offspring with sufficient accuracy to say whether the Galton-Pearson law will fit this case as it fits so many others; but they do enable us to say that the *sign* of these correlations—the first negative coefficients of direct parental inheritance yet published—is in accordance with that law, and that the results obtained do not demonstrably contradict it in other respects.

OFFSPRING OF HYBRIDS.

Hybrids have been paired together or crossed with albinos; a third group of unions between hybrids and extracted albinos may perhaps be treated as belonging to this generation. The results of these three kinds of unions will be considered separately.

Offspring of hybrids paired together.

The unions of hybrids gave altogether 555 young; which were divisible into three groups according to the characters of the eyes and coat: these were

Albino	137
Coloured or piebald with dark eyes	287 or 284*
Coloured or piebald with pink eyes	131 or 134
	555

Dividing these mice according to their mode of walking we find that there are

Waltzing	97
Normal	458
	555

It is clear that the albinos occur in this generation with a frequency indicated by a purely Mendelian theory of albinism regarded as a simple unit character, allelomorphic to a single unit character in the waltzing race; that hypothesis leads us to expect that a quarter of the offspring of hybrids paired together will be albinos; and since $\frac{555}{4} = 138\cdot75$, the observed result is in excellent accord with it; the difficulty in this, as in all attempts to apply Mendel's hypothesis, is to discover what are the unit characters concerned.

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* There is unfortunately a doubt concerning the eye-colour of three mice; these are all lilac in colour, and I am practically sure that they had pink eyes. I have never observed a lilac mouse which had dark eyes; the omission of the letter *p* after the lilac mice catalogued in my second paper (*Biometrika*, Vol. II. Part 2, pp. 168, 169) is due to inadvertence in proof reading.

In the preliminary account of the experiment it was evident that the proportion of pink-eyed individuals, with colour in the coat, was also nearly $\frac{1}{4}$; the number now observed, namely at least 131 and possibly 134, is also a fair approximation to a quarter. So far then the results are not inconsistent with the truth of Mr Bateson's suggestion (*Nature*, March 19, 1903) that the character allelomorphic to albinism is pink eye with colour in the coat.

Using Mr Bateson's original notation and denoting albinism by the symbol G, pinkness of eye with some colour in the coat by the symbol G', the generation is at first sight fairly represented by the formula

$$GG + 2GG' + G'G'$$

where GG' represents a heterozygous union between the albino and its allelomorphic element—resulting, for some reason which the Mendelian hypothesis does not provide, in a dark-eyed mouse with a coat-colour variable and generally unlike that of either pure parent.

The difficulties of this hypothesis are, however, great, even when we confine our attention to the frequency of the various kinds of individuals in the group, without considering the ancestral and fraternal correlations. In this as in the preceding generation the variability of the dark-eyed mice (heterozygotes of Bateson's hypothesis) is so great that it is impossible to regard each of them as resulting from the union of similar Mendelian elements; and the relation between pinkness of eye and coat-colour is in the same way inexplicable on the view that there is only one kind of element G'.

The 131 pink-eyed mice are all of colours a, b, or f, that is yellow, fawn-yellow, or lilac; and these must on any Mendelian view represent more than a single kind of gametic element; but if more than one such element be present, the original waltzing mice must have contained more than a single kind of unit G', and we have to consider Mr Bateson's second hypothesis (*Nature*, May 14), which is that in the formula already given the symbol G' must be regarded as denoting any one out of a series of different allelomorphic units, each leading, when mated with its like, to the production of a pink-eyed mouse with some colour in its coat. The hypothesis which involves the smallest number of kinds of elements is that one of the colours a, b, or f is a compound character resulting from the union of the other two: we should then have to consider the three kinds of pink-eyed mice with colour in the coat as of different gametic constitution; if we regard yellow and lilac as "pure," we should have to regard the yellow pink-eyed forms as "pure dominants," say of constitution $G_1'G_1'$, the lilac pink-eyed forms as pure, and of constitution $G_2'G_2'$, the fawn-yellow pink-eyed forms being heterozygotes of composition $G_1'G_2'$.

This hypothesis fails in several ways to meet the facts; and since the objections to this apply with greater force to any Mendelian hypothesis involving a larger number of allelomorphic units, it is worth while to consider them in some detail. The two kinds of elements G_1' and G_2', which are here assumed to be manifested in the pink-eyed young with coloured coats, must be derived from the waltzing grandparents, for the hypothesis of gametic purity at once excludes any attempt to derive them from the albino ancestors: hence *either* each original waltzer used must have been a heterozygote of composition $G_1'G_2'$, *or* two kinds of pure waltzers $G_1'G_1'$ and $G_2'G_2'$ must have been employed. I am convinced that neither of these consequences of the hypothesis considered is true. Two mice of constitution $G_1'G_2'$ paired together should have given young of character and relative frequency indicated by

$$G_1'G_1' + 2G_1'G_2' + G_2'G_2',$$

so that all three of the colours observed among the pink-eyed offspring of hybrids must have appeared among the offspring of waltzing mice paired together. Now I am aware that lilac and white waltzing mice are bred by dealers, and I am familiar with their characters; I am absolutely sure that no one among the many young bred from the waltzing mice used in these experiments was lilac in colour.

The second hypothesis that two kinds of waltzing mice were employed involves the belief that one of these was lilac; and this is also untrue.

The known history of the waltzing mice used is therefore incompatible with the view that a and f (yellow and lilac) represent pure gametic elements of which b (fawn colour) is the heterozygote. It is similarly impossible to regard a or f as a character of a heterozygote, b and the remaining character being pure; for this hypothesis also would involve the appearance of lilac individuals in a quarter (or in the whole) of the young produced by waltzing mice bred together. The behaviour of the waltzing mice when bred together is alone sufficient to destroy the validity of any hypothesis, involving numerous elements G', which does not depart from Mendel's doctrines.

Mr Bateson has already proposed (*Nature*, April 23, 1903) to regard the waltzing mice used as heterozygous; if he has once refused to accept the statements as to their purity he or others may well do so again. Let us therefore see what happens under these circumstances. The hybrids produced by pairing a heterozygous waltzing form $G_1'G_2'$ with a homozygous albino GG will be of two kinds, GG_1' and GG_2'; it is said that these will be dark-eyed and have some colour in the coat, but at present there is no means of distinguishing between them: all we know on this hypothesis is that the hybrids are of two kinds which are present in equal numbers. These hybrids, being indistinguishable, will be paired at random by any experimenter; so that the offspring of hybrids now considered will result from unions of three kinds, of which one will probably be twice as frequent as the other; there will be—

$$\begin{array}{rcl} GG_1' \times GG_1' & \text{giving} & GG + 2GG_1' + G_1'G_1', \\ 2\,(GG_1' \times GG_2') & ,, & 2\,\{GG + GG_1' + GG_2' + G_1'G_2'\}, \\ GG_2' \times GG_2' & ,, & GG + 2GG_2' + G_2'G_2', \end{array}$$

the offspring of hybrids being a series of individuals represented in composition and in relative frequency by

$$4GG + 4GG_1' + 4GG_2' + G_1'G_1' + 2G_1'G_2' \times G_2'G_2',$$

where all the zygotes of constitution $G'G'$ have pink eyes and some colour in the coat. The sum of these is a quarter of the whole population, and we have seen that this is compatible with the observed result; but the three colours in the coat should occur with relative frequency 1 : 2 : 1, or among the 131 (possibly 134) individuals actually found there should be if we call *a* and *f* G_1 and G_2—

$G_1'G_1'$ ...... 32·25 instead of 19 observed.
$G_1'G_2'$ ...... 64·50 ,, 80 observed.
$G_2'G_2'$ ...... 32·2 ,, 32 or 35 observed.

Taking either of the possible numbers of pink-eyed lilac mice we find that these results are not impossible on the hypothesis put forward, but the odds against results so divergent as these or more so are about 60 or 70 to 1.

The distribution of pink-eyed young might therefore, if not very plausibly, be accounted for by a purely Mendelian hypothesis if that hypothesis did not involve the appearance of lilac individuals in the offspring of pure-bred waltzing mice when paired together. The absence of such individuals might be explained by a departure from the Mendelian statements such as that made by Bateson in several cases, and it might be assumed that the pure waltzing mice have their eye-colour and coat-colour determined by a compound allelomorph $(G_1' + G_2')$ not resolved into its components during gametic-formation in a pure-bred individual. This view is consistent with the behaviour of the pure waltzing strain, but it does not lead to the observed frequencies among the offspring of hybrids. The hybrid zygote will on this view be of constitution $GG_1' + GG_2'$; and two such hybrids when crossed will give in every 16 young

$GG + GG$ ...... once
$GG + GG_1'$ ...... twice
$GG + GG_2'$ ...... twice
$GG_1' + GG_2'$ ...... four times
$GG_1 + GG_2'$ ...... twice
$GG_2' + G_1'G_1'$ ...... twice
$G_1'G_1' + G_2'G_2'$ ...... once
$GG + G_1'G_1'$ ...... once
$GG + G_2'G_2'$ ...... once

and a zygote of elements G_1' only, or G_2' only can never be produced without assuming that remarkable elimination of some elements from every gamete suggested by Mr Bateson (*Proc. Camb. Phil. Soc.* XII.), and so treating the phenomena of colour inheritance in a manner not only foreign to all Mendel's conceptions, but leading to obvious absurdity if applied to any set of characters other than colours.

A further difficulty involved in any of these hypotheses is the correlation between coat-colour and eye-colour. Pink eyes are confined, as has been said, to mice with yellow, fawn-yellow, or lilac coats, and all lilac mice whose eye-colour is certainly known have pink eyes; but dark-eyed mice with yellow or fawn-coloured coats occur in this and in the preceding generation, and their presence is difficult to explain on either of the hypotheses examined.

The difficulties we find when we try to describe the various classes of individuals found among the offspring of hybrids are increased when we consider the great variability both in the colour of the coloured patches and in their extent among the individuals of any class, the amount of which may be gathered from Tables I.—VII.

The correlations between the various characters exhibited by the offspring of hybrids and the characters of their ancestors are quite inexplicable on any hypothesis involving the purity of the albinos. The correlation between individuals of this generation and the purity or impurity of their albino grandparents—that is the measure of the effect of ancestral pigmentation transmitted through the albino parent—is evident from Tables XX.—XXIII. These correlations are all negative,—the sign, taking the scales in the directions given in the tables, showing that the amount of whiteness is less among the individuals descended from pure-bred albino grandparents, the coat-colour itself being darker; so that the relation between the albinos used in the original cross and the offspring of hybrids has the same sign as that between the albinos and the hybrids themselves; the correlation, however, is apparently larger, instead of being smaller as might have been expected, the value of r for both colour and whiteness being about $-0{\cdot}3$ (Tables XX., XXI.). A correlation so large as this is far beyond the probable error of the determination, and it is of course absolutely fatal to any theory which involves the "gametic purity" of the albinos.

The only character of the pure-bred waltzing grandparents which varies enough to permit of its correlation with the offspring of hybrids being determined, is the extent of the coloured patches. Dividing the waltzing grandparents into α and β as already explained, the correlations are fairly uniform, the coefficient for colour and for amount of whiteness being about $0{\cdot}3$ (see Tables XXIV. and XXV.), as in the previous generation; the sign of the correlation between colour in the hybrids and amount of whiteness in their waltzing parent (which of course depends upon the order in which the colours are arranged upon the arbitrary scale) is *negative*, showing that the waltzing mice with a greater amount of white produce hybrids with darker coat-colour; between waltzing grandparents and the offspring of hybrids the sign is, however, positive for the same arrangement of colours, so that while the intermediate hybrid offspring of waltzing mice with a large amount of white coat are darker than the average of hybrids, the young produced by such offspring paired together are on the whole lighter than the average.

It must be remembered that this relation between the amount of white coat in one generation is a relation of cross inheritance, depending on (though not always simply proportional to*) the product of the coefficients of direct inheritance and of organic correlation. We have seen that the coefficient of organic correlation between amount of whiteness and coat-colour is negative in the hybrids themselves; in their offspring it has changed its sign and become positive, so that we see the way in which the sign of the coefficient of cross grandparental inheritance has become changed. We see then that both the colour of the coat and the amount of white fur in the offspring of hybrids are correlated about as strongly with characters of one set of grandparents as with those of the other; neither the waltzing grandparents nor the albinos are dominant in the sense that they alone determine the characters of the generation, neither are recessive in the sense that they take no part in such determination. It may be urged that the correlations just determined are without value because the offspring of hybrids are obviously divisible into two groups, albinos and others—and perhaps into three. There is some indication that the correlations between the albinos and their waltzing grandparents is negative, the grandchildren of the whiter waltzers containing a distinctly smaller percentage of albinos than the grandchildren of waltzers with a larger amount of coat-colour: the numbers descended from the various waltzing grandparents are shown in Tables XXIV. and XXV., and it will be seen that the deviation from Mendelian expectation is only great enough to be suggestive among the 112 offspring of hybrids whose waltzing grandparents were both of type α. The number of albinos which should be found in this group is 28, and the probable error of the expectation is $0{\cdot}6745\sqrt{\frac{1}{4} \times \frac{3}{4} \times 112} = 3{\cdot}09$; the number of albinos actually found is 18, showing a deviation from the most probable result equal to more than three times the probable error, the chance of a deviation so great as this being about 0·0015, or the odds against it about 370 to 1.

If, however, we exclude the albinos, and calculate the correlation between the coat-colour or the amount of white fur in the remaining individuals, and the whiteness of their waltzing grandparents, we obtain values very closely similar to those already given, so that in this case at least the apparent dimorphism of the young has no effect upon the grandparental correlations.

The parental correlations are considerable, and curiously different for different characters. The correlation between the amount of white coat in hybrids and in their offspring is about 0·7 for both father and mother, showing that the whiter parents produce a markedly greater proportion of young in which whiteness predominates than are produced by the darker parents; they also produce a larger proportion of pure albinos.

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* Cf. Pearson, "On the Laws of Inheritance in Man," *Biometrika*, Vol. II. Part IV. pp. 384—5.

In coat-colour the correlation between parents and offspring is much less, being about 0·2 for both parents. The cross-inheritance, as measured by the correlation between coat-colour of father or of mother and whiteness of young, is again positive (in accordance with the positive organic correlation between these two characters in the young), and its value is about 0·2.

These various correlations cannot be adequately discussed without attempting a study of the effects due to the selection of parents during the experiment, too difficult for any but a trained mathematician. The hybrids were to a large extent paired together so that the members of a pair were of similar colours, the correlation between male and female members of a pair (weighted with the number of young produced) being about 0·4, so that the coefficient of assortative mating has changed from $+1$ in the ancestors of the pure-bred mice, through -1 in the unions which produced the hybrids, to about 0·4 in unions resulting in the generation now described. The amount of whiteness in the coat of the hybrids was also selected, the correlation between male and female in the unions made being over 0·9; this difference in the degree of assortative mating may possibly account for the difference between the parental correlations in the two cases.

We see, however, that both the colour and the amount of whiteness in the coat are variable characters, depending to a sensibly equal extent on characters transmitted by each of the pure-bred parents of the hybrids, so that there is no question of dominance on the part of one or other parent, and no possibility of regarding the characters of the generation examined as depending solely on the individuals paired in the original cross union, apart from their ancestry. In other words, we see that here, as in the hybrid generation, the phenomena observed must be formulated in some way or other in terms of the whole ancestry, and the idea of "gametic purity" is therefore excluded.

Waltzing occurs in only 97 out of the 555 individuals resulting from the union of hybrids. When we compare this with the number of pink-eyed individuals (131—134) or of albinos (137) we see that the proportion of waltzing individuals cannot be regarded as a possible quarter. The probable error of the expectation that a quarter of the individuals will waltz is, on the Mendelian hypothesis, $0{\cdot}6745\sqrt{\frac{1}{4}\times\frac{3}{4}\times 555} = 6{\cdot}88$ only, and the observed deviation is $138{\cdot}75 - 97 = 41{\cdot}75$, the odds against so great a deviation being rather more than 50,000 to 1. As the result here obtained differs from Mendelian expectation in the same direction as that already obtained by von Guaita* and to an extent consistent with the agreement of both, the evidence that the waltzing character does not segregate in Mendelian proportions is very strong.

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* "Versuche mit Kreuzungen von verschiedenen Rassen der Hausmaus," *Ber. d. naturforsch. Gesellsch. Freiburg*, Bd. x. 1898, Bd. xi. 1900.

Waltzing is completely recessive to normal walking, disappearing entirely in the hybrids resulting from the cross; its correlations with other characters, parental, grandparental or fraternal, are always small and generally insensible. Except for the fact that the proportion of waltzers among the offspring of hybrids is so widely divergent from that indicated by the theory, waltzing is thus more nearly Mendelian in its behaviour than any of the characters examined. The distribution of waltzing individuals among the various families (see Table A) is, however, less regular than it should be, and in this way a sensible fraternal correlation is established (Table XIX.) which is not in accord with Mendelian theory.

HYBRIDS CROSSED WITH ALBINOS.

Unions between hybrids and albinos produced 746 young, of which 368 were albino, the rest being piebald or self-coloured. The gap between albinos and coloured individuals was wider than among the offspring of hybrids paired together, since the Group 1, including individuals in which the pigmented area is smallest, was entirely absent, and only eight individuals fell into the next group 2, the majority of individuals which were not albino being of degree 5 or 6. The coloured individuals had dark eyes, and none showed the waltzing habit. The range of coat-colours was less than among the offspring of hybrids paired together, since lilac did not occur. The relative frequency with which the different colours occurred was strikingly different from that seen among the offspring of hybrids, as will be gathered from the following table:

Percentage frequency of the Colours in (a) Coloured Offspring of Hybrids paired together, (b) Coloured Offspring of Hybrids and Albinos.

Colour	Hybrid × Hybrid	Hybrid × Albino
a	7·66 °/。	6·08 °/。
b	22·97 °/。	3·17 °/。
c	36·36 °/。	44·18 °/。
d	4·55 °/。	14·55 °/。
e	18·66 °/。	29·10 °/。
f	8·37 °/。	0·00 °/。
g	1·44 °/。	2·90 °/。
	100·01	99·99

It will be seen that the coloured offspring of hybrids and albinos, which have more white in their ancestry than the offspring of hybrids alone, are characterised *first* by having considerably less white fur, and *secondly* by the greater frequency of wild-colour and black, as compared with yellow and fawn-colour—that is, by the presence of black pigment in larger quantity. This increase of blackness with increase in the number of albino ancestors is very remarkable, and no explanation suggests itself at present; it is however in accord with the negative correlation already mentioned between purity of ancestry among the albinos employed in making the original cross and the darkness of the hybrids.

The albinos of the group seem more obviously distinct from the rest than do the albinos among the offspring of hybrids, and the ancestral correlations are materially affected by their retention or omission.

Retaining the albinos the correlation between whiteness of coat and purity of the albino grandparent is about – 0·15 (cf. Table XLV.); between whiteness of coat in coloured individuals alone and purity of albino grandparent the coefficient rises to about – 0·25. We have here a further proof of the extent to which the ancestry of the "recessive" albino affects the coloured descendants of the cross. The correlations with the albino *parent* are too small to be worth noticing until the probable error of the method employed for their determination can be given; the data are given in Tables XLIX. and L., where it will be seen that nearly all the albinos used as parents were pure-bred, so that the determination of correlations is difficult.

The hybrid parent appears to be more closely correlated with the young, both in colour and in amount of whiteness, than the albino, the correlation in both characters being about 0·2, the value found among offspring of hybrids paired together.

HYBRIDS CROSSED WITH EXTRACTED ALBINOS.

The object of this experiment was to determine if the percentage of albinos produced by such crosses would be different from that produced by crosses between hybrids and pure albinos. The number of albinos obtained—59 out of 120—is of course an excellent experimental half; but the following considerations should be carefully weighed, (i) the albinos used were not all produced by pairing two hybrids; in many cases (see Table D) they were produced by crossing hybrid and albino, (ii) the hybrids used were in some cases (G_{12}, G_{14}, G_{15}, G_{16}, G_{17}, G_{19}, G_{20}) the offspring of waltzers and extracted whites, (iii) the character the percentage of which one is trying to diminish in the offspring is identical with that of one of the parents: in offspring of extracted hybrids one was able to diminish the number of albinos by diminishing the amount of albino ancestry of the extracted hybrids; but in this experiment, while one does diminish the albino ancestry, one of the *parents themselves* is always albino; so that the effect of the diminution of albino ancestry is rather swamped.

If separate tables are made for, (i) hybrids crossed with albinos produced by the union of hybrids, (ii) hybrids crossed with albinos produced by hybrids paired with albinos, and (iii) hybrids from extracted white crossed with extracted albinos, the numbers become so small as to be useless to base arguments upon.

The occurrence of pink eyes in seven of the young, or five per cent. of the number produced, distributed among five families (more than one-fifth of the whole number), is clear evidence that these extracted albinos have a power of hereditary transmission, dependent upon their ancestry, different from that of albinos whose ancestry contains no pink-eyed waltzers.

GRANDCHILDREN OF HYBRIDS.

The children of hybrids consisted roughly of a quarter albinos, a half dark-eyed forms with coloured coats and a quarter pink-eyed mice with colour in the coat. The extracted albinos are unquestionably the recessives: the dark-eyed mice with coloured coats I have termed the extracted hybrids; partly because they occur in the proportion of 50 °/₀ and partly because they are asserted by Bateson and Castle to be what I have called them. The pink-eyed forms with colour in the coat which occur in the Mendelian proportion of a quarter I have called extracted dominants for similar reasons: I feel quite confident that Mendel himself would have sanctioned this classification, since the proportions agree closely with those which he obtained with his peas.

The grandchildren of hybrids will be treated of under the following headings: (i) offspring of extracted recessives $RR \times RR$, (ii) offspring of extracted hybrids $DR \times DR$, (iii) offspring of extracted dominants $DD \times DD$.

(i) *Offspring of Extracted Recessives.*

As could have been predicted with no fear of contradiction by those who are familiar with fancy mice the extracted albinos when paired together produce only albinos. For some reason I have been unable to breed from waltzing individuals of this category, and therefore the number of young which waltz is small, but it is far below that which would appear on Mendelian expectation, which is 1 in 12. For the albinos may be as regards waltzing either dominant or hybrid, i.e. the kinds of pairs of albinos that can be made are three:

(i) $DD \times DD$.
(ii) $DD \times DR$.
(iii) $DR \times DR$.

Of these pairs, (i) and (ii) should produce no waltzers, and (iii) should produce 1 in 4. The whole number of young obtained was 94, and of these only *two* waltzed!

(ii) *Offspring of Extracted Hybrids.*

I think that the most conclusive results which I have obtained are given by the results of pairing extracted hybrids: as the reader is aware, hybrids were paired with hybrids ($DR \times DR$) and also crossed with albinos ($DR \times RR$), the former giving offspring which may plausibly be regarded as consisting of $\frac{1}{4}DD + \frac{1}{2}DR + \frac{1}{4}RR$, the latter $\frac{1}{2}RR + \frac{1}{2}DR$. So that, when pairing the children of hybrids to produce the generation which we are now considering, two kinds of extracted hybrids were available, (i) the result of $DR \times DR$ (which I will denote $H \times H$ = hybrid × hybrid) and (ii) the result of $DR \times RR$ (which I will call

$H \times A$). With these two kinds of extracted hybrids three kinds of crosses can be made:

1. $(H \times H) \times (H \times H)$.
2. $(H \times H) \times (H \times A)$.
3. $(H \times A) \times (H \times A)$.

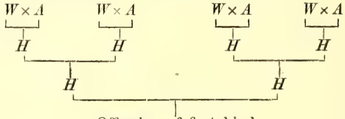
Now in Mendelian language these kinds of pairs are all $DR \times DR$, for the DR produced by $DR \times RR$ is not different from the DR produced by $DR \times DR$. And the similarity of these formulae is characteristic of the Mendelian conception of the reproductive organs of the hybrids.

For it is well known that according to this view the hybrid contains equal numbers of germ-cells which produce the dominant character, and of those which produce the recessive; and this is said to be true of the hybrids however far the individual is removed from the original cross, whether it is the result of the cross (i.e. the hybrid) or the great-great-grandchild of this. This is the ground on which the doctrine of the purity of the germ-cells and the law of ancestral heredity flatly contradict one another; the former asserting that $DR \times DR$ will produce 25 °/₀ DD, 50 °/₀ DR and 25 °/₀ RR for a very great if not an infinite number of generations; the latter maintaining that the further the individual hybrid under consideration happens to be removed from the cross the less albinos will it produce: and that two hybrids whose mothers were albinos will produce more albinos than would two hybrids who have no albinos in their pedigree later than their great-great-great-grandmother. This seems to me to afford a case in which experiment could provide a decisive answer. I have made an experiment of this kind: that is, I have tried to see if by pairing together hybrids with different amounts of albino ancestry I could obtain different percentages of albino individuals among the offspring. I have not had time to do this by producing successive generations of hybrids and counting the number of albinos in each: but I have done it by observing the difference between the results of making crosses of form $(H \times H) \times (H \times H)$, $(H \times H) \times (H \times A)$ and $(H \times A) \times (H \times A)$.

The ancestry of these kinds of pairs is perhaps brought more vividly before the reader's mind by considering the following pedigrees:

(i)

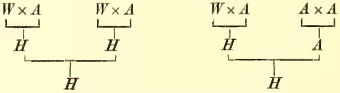
$(H \times H) \times (H \times H)$



Offspring of first kind.

(ii)

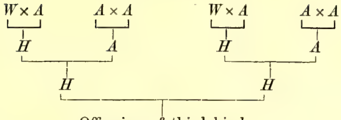
$(H \times H) \times (H \times A)$



Offspring of second kind.

(iii)

$(H\times A)\times(H\times A)$



Offspring of third kind.

It is evident that the amount of albino ancestry is largest in (iii), smaller in (ii), and smaller still in (i). The doctrine of the gametic purity asserts that a series of individuals having any of the pedigrees above represented should contain 25 per cent. of albinos and 75 per cent. of coloured mice. The law of ancestral inheritance proclaims that the percentage of albinos will be greater in (ii) than in (i) and greater in (iii) than in (ii): which is exactly what we find to be the case.

The number of albinos produced by each kind of pair is seen at a glance in the following table.

Origin of the hybrids mated	Number of young	Number of albinos	Albinos per cent.
$(H\times H)\times(H\times H)$	93	10	10·75
$(H\times H)\times(H\times A)$	107	20	18·69
$(H\times A)\times(H\times A)$	121	30	24·79

The amount of whiteness in the various coloured individuals resulting from these unions, and the colour of their coats, may be gathered from Table E on p. 35. An interesting feature is the reappearance of lilac in the grandchildren of unions between hybrids and albinos, though this colour has been seen to be absent from the immediate progeny of such unions.

EXTRACTED HYBRIDS CROSSED WITH EXTRACTED ALBINOS.

In the unions just described, hybrids of various kinds were paired together. By pairing such hybrids with extracted albinos we should, on the Mendelian view, produce equal numbers of albinos and of dark-eyed hybrids. Out of 91 young actually produced, 36 were albino; this is not an impossible approximation to a Mendelian half, but it is so bad as to afford a strong suggestion that the ancestry of the albinos used has affected the result, and this suggestion is confirmed by the fact that six of the young produced have pink eyes, a phenomenon never observed when albinos of ancestry which does not contain waltzers are crossed with these hybrids. See Table F, p. 36.

OFFSPRING OF EXTRACTED DOMINANTS.

(a) *Extracted Dominants paired together.*

Pink-eyed forms with colour in the coat have been paired together, but the results so far obtained are too few to be of great value. The whole number of young, obtained from seven unions, was 32 (see Table H, p. 37). The young were all pink-eyed, but one was completely albino.

It has already been pointed out that there is more than one kind of pink-eyed mouse with colour in the coat, and the difficulties which arise, when we attempt to derive these various kinds of mouse from the pure-breeding waltzer by any Mendelian process, have been indicated.

So far as the observations go, they suggest (1) that a proportion of albinos, not yet determined, results from these unions; (2) that lilac mice, paired together, breed true to coat-colour; (3) that dark-eyed mice are not produced in any large proportion; (4) that the amount of whiteness in the coloured young is highly variable.

(*b*) *Extracted Dominants paired with Albinos.*

"Extracted dominants" have been paired with albinos in order to find out whether such unions behave according to Mendelian expectation. If the so-called extracted dominants were really of the constitution suggested by the name given to them, they should of course, when paired with albinos, produce a series of hybrids like those resulting from the original cross, albinos being absent. This was not found to occur. Out of 98 young produced, 12 were albinos—practically the same percentage as that given by one series of dark-eyed hybrids paired together—while one pink-eyed individual occurred.

Most of the albinos used in making these crosses were "extracted" from the offspring of hybrids paired with albinos, as will be seen from the pedigrees given in Table G, p. 36; of the 98 young produced, 63 were from unions between such "extracted" albinos and the extracted dominants; the seven unions between extracted dominants and albinos which did not include pink-eyed fawn-and-white waltzers among their immediate ancestors produced 35 young, of which no less than 10, distributed among four of the unions, were albino; of the three unions of this kind which produced no albinos, one was between a pure-bred albino and the same "dominant" individual which produced albinos when mated with another pure-bred albino; there remains only two unions (Nos. 2*H* 79 and 2*H* 80) between pure albinos and "extracted dominants," which did not produce albino young; as these two unions produced only 12 mice, their evidence is not conclusive.

The experiments seem to show (1) that pink-eyed mice with colour in the coat are not always, if ever, "pure dominants," since they do at least generally produce some albinos when paired with albino mice of appropriate race; (2) that the "extracted recessive" albino mice behave differently from albinos of other ancestry.

The second result, together with other evidence already given, disproves the "pure recessive" nature of extracted albinos, the first makes it extremely doubtful whether "pure dominants" exist.

CONCLUSIONS.

The experiments described appear to justify the following statements:

1. When the race of waltzing mice used is crossed with albino mice which do not waltz, the waltzing habit disappears in the resulting young, so that waltzing is

completely recessive in Mendel's sense; the eye-colour of the hybrids is always dark; the coat-colour is variable, generally a mixture of wild-grey and white, the character of the coat being distinctly correlated with characters transmitted both by the albino and by the coloured parent. There is thus no proper dominance in Mendel's sense, so far as eye-colour and coat-colour are concerned, the hybrids differing always in eye-colour and generally in coat-colour from *both* their parents.

2. When the hybrids, produced from the cross described, are paired together, the resultant young exhibit a segregation into three groups, so far as eye-colour and coat-colour are concerned, into two so far as regards the waltzing habit. The phenomenon of segregation is closely similar to that described by Mendel, and in the colour, whether of eyes or of fur, the proportions are closely identical with those observed by him, a quarter of the young resembling their albino grandparent, half representing their hybrid parents, and a quarter resembling their waltzing grandparents in so far that they have pink eyes and some coloured fur, but differing from any of their immediate ancestors in the range of coat-colours exhibited. The proportion of individuals which exhibit the waltzing habit is less than one-fifth of the whole number of young, and is not a Mendelian proportion.

3. When hybrids are paired with albinos, half the young produced resemble their albino parent, half resemble their hybrid parent; this result is in accord with Mendel's theory.

4. The correlations between coat-colour in the hybrids and descendants on the one hand, and the ancestry of their albino grandparents on the other, are not consistent with the view that albinism is a recessive Mendelian character, transmitted "gametically pure" by any homozygote which possesses it.

5. The behaviour of "extracted albinos," "extracted hybrids," and "extracted dominants" is not consistent with any theory of gametic purity yet propounded. There is no evidence that any individuals which could be properly described as "pure dominants" or "pure recessives" exist among the whole series produced.

6. The effect of varying ancestry is so great, in every case in which it has been examined, as to show that the phenomena observed cannot be adequately described except in terms of the ancestry of all the individuals used as parents.

7. There is no evidence to show whether the ancestral correlations observed are consistent or not with the consequences which would follow from the application to this particular case of the Galton-Pearson law of inheritance; the only consequence of that law which can at present be deduced, namely, the negative correlation between one parent and the offspring of the first cross, is in agreement with observation.

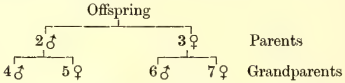
8. In this, as in many other cases, the characters of the hybrids produced by crossing two races which have been long distinct strongly suggest reversion to ancestral characters.

I cannot bring these observations to a close without expressing my gratitude to those to whom it is due. Professor Weldon has helped to bridge over a gap due to my absence from Oxford for two months, and has given me assistance in tabulating the correlations. I owe thanks to Professor Pearson for giving aid in the calculation of the correlation coefficients, and in the criticism of some of the conclusions drawn from them. I am also very grateful to my friend Mr E. H. J. Schuster for much arithmetical help very generously given. Last, and almost, therefore, not least, to Mr Frank Sherlock I owe a debt of gratitude which is difficult to express. Mice are living things, and Mr Sherlock is almost entirely responsible for supplying them with their daily needs for more than a year with an industry and patience which is beyond all praise. The sanitary condition of a room containing some fifteen hundred mice is sufficient testimony to his conscientiousness and competence: he is in a way more directly responsible for the carrying out of the experiment than anyone else. For these things he merits my lasting gratitude, which is tendered to him in full measure.

APPENDIX I.

List of all Mice bred during the Experiment, with the Characters of their immediate Ancestors.

Explanation of the Tables:—Every line of the table contains a single family; the columns on the left, numbered 2—7, describe the characters of the ancestors. The notation used is nearly that of Mr Galton (see *Biometrika*, Vol. II. p. 237), and is shown by the following pedigree, in which every even number denotes a male, every odd number a female ancestor:



Every individual is described by a series of symbols denoting the amount of white fur in its coat, the nature of the colour in its coat, its eye-colour, and its power of waltzing. The following symbols are used:

A = Albino; in the columns recording ancestry, A alone means a pure-bred albino, while $A\times$ denotes a cross-bred albino (used only in recording ancestors).

a = Yellow.
b = Fawn colour.
c = Wild-grey.
d = Dark wild-grey.
e = Black.
f = Lilac.
g = Chocolate.

α is used only of pure-bred waltzers with much white in the coat.

β is used only of pure-bred waltzers with less white in the coat than is signified by α.

W = A pure-bred waltzer, fawn and white, with pink eyes.

w = A cross-bred with waltzing habit.

p = With pink eyes. (*Note* that since all albinos and all the pure-bred waltzers used had pink eyes this symbol is omitted in describing pure-bred ancestors. When it is omitted in other cases, the individual referred to had dark eyes.)

The figures, Nos. 1—6, denote amounts of white fur in the coat, as explained on p. 1.

TABLE A.—*Results of crossing Waltzing Mice with Albinos.*

Catalogue Number	Parentage		Offspring	Number in Litter
	3	*2*		
1	*A* ×	*Wa*	1*c*, 1*c*, 2*c*, 2*d*, 3*c*, 3*c*	6
6	*A* ×	*Wβ*	2*c*	1
7	*A*	*Wa*	2*c*, 2*c*, 2*d*, 3*c*, 3*d*, 5*c*, 5*c*	7
8	*A*	*Wβ*	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	6
9	*A* ×	*Wa*	2*c*, 2*c*, 2*c*, 2*c*, 2*c*, 2*d*	6
12	*A*	*Wa*	5*a*, 5*a*, 5*c*, 5*c*, 5*c*	5
13	*A*	*Wa*	3*c*, 3*c*, 5*c*, 5*d*	4
16	*A* ×	*Wβ*	3*c*, 3*c*, 3*c*, 4*c*, 4*c*	5
20	*A*	*Wa*	2*c*, 2*d*, 2*d*, 3*d*, 5*d*, 5*d*	6
27	*Wa*	*A*	2*e*	1
33	*Wa*	*A*	5*c*	1
45	*A*	*Wa*	2*d*, 2*d*, 2*d*, 2*d*	4
53	*Wβ*	*A*	4*c*	1
59	*Wa*	*A*	3*d*, 6*d*	2
61	*A*	*W*	2*c*, 3*c*, 4*c*, 5*c*, 5*c*, 5*c*, 5*c*	7
62	*A*	*Wβ*	2*c*, 3*c*, 3*c*, 5*c*, 5*c*, 5*c*	6
66	*W*	*A*	5*c*	1
72	*W*	*A*	5*c*	1
73	*A*	*W*	3*c*, 3*c*, 3*c*, 5*c*, 5*c*, 5*c*	6
74	*A*	*W*	3*c*, 4*c*, 4*c*, 4*c*, 4*c*, 4*c*, 4*c*	7
75	*A*	*W*	1*c*, 2*c*, 2*c*, 3*c*, 4*c*	5
77	*A*	*Wβ*	4*c*, 4*c*, 4*e*, 5*c*, 5*c*, 5*c*, 5*c*, 5*e*	8
78	*A*	*Wβ*	2*e*, 3*e*, 5*d*, 5*e*	4
82	*Wβ*	*A*	3*c*, 5*c*	2
84	*A*	*Wβ*	5*a*, 5*a*, 5*a*, 5*a*, 5*a*, 5*c*, 5*c*, 5*c*, 5*c*	9
85	*A* ×	*Wa*	3*e*, 3*e*, 4*d*, 5*d*, 5*d*, 6*d*, 5*e*	7
86	*A*	*W*	3*c*, 3*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	7
90	*A*	*Wa*	5*c*, 5*c*	2
91	*Wa*	*A*	6*c*	1
94	*Wa*	*A*	3*c*, 3*c*	2
100	*A*	*Wβ*	2*c*, 3*c*, 3*c*, 3*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	9
101	*A*	*Wβ*	2*c*, 3*c*, 3*c*, 4*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	9
102	*A*	*Wβ*	3*c*, 4*c*, 4*c*, 4*c*, 4*c*, 5*c*, 5*c*, 5*c*, 5*c*	9
103	*A*	*W*	2*c*, 3*c*, 3*c*, 3*c*, 5*c*, 5*c*, 5*c*, 5*c*	8
104	*A*	*W*	1*c*, 2*c*, 2*c*, 3*c*, 3*c*, 4*c*, 5*c*	7
107	*Wa*	*A* ×	3*e*, 5*c*	2
108	*Wa*	*A* ×	5*c*	1
110	*Wa*	*A*	3*c*, 3*c*	2
111	*A*	*Wa*	5*a*, 5*a*, 5*a*, 5*a*, 5*a*, 5*d*, 5*d*, 5*d*, 5*d*, 5*d*	10
112	*A* ×	*Wβ*	2*c*, 2*c*, 2*c*, 3*c*, 5*c*	5
113	*A* ×	*W*	3*c*, 3*c*, 4*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	8
114	*A* ×	*W*	2*c*, 3*c*, 3*c*, 5*c*, 5*c*, 5*c*	6
117	*A* ×	*W*	3*c*, 3*c*, 3*c*, 4*c*, 4*c*, 4*c*, 4*c*	7
118	*A* ×	*Wa*	4*c*, 4*c*, 5*c*, 5*c*, 5*c*	5
120	*A* ×	*Wa*	2*c*, 2*c*, 3*c*, 3*c*, 3*c*, 4*c*, 4*c*	7
142	*A* ×	*Wa*	2*c*, 2*c*, 2*c*, 3*c*, 5*c*, 5*c*	6
144	*A*	*W*	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	6
147	*A* ×	*Wβ*	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	6
159	*A*	*W*	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	6
160	*A*	*Wβ*	5*c*, 5*c*, 5*c*, 5*c*, 5*c*	5
161	*A*	*W*	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	6
162	*A*	*W*	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	6
163	*A*	*W*	5*c*, 5*c*, 5*c*, 5*c*, 5*c*	5
165	*A*	*W*	4*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	7
166	*A*	*W*	3*c*, 4*c*, 5*c*, 5*c*, 5*c*	5
167	*A*	*W*	4*c*, 4*c*, 5*c*, 5*c*, 5*c*	5
169	*Wβ*	*A*	6*c*, 4*c*	2
170	*A* ×	*Wa*	3*c*, 3*c*, 4*c*, 5*c*, 5*c*	5
171	*A* ×	*Wa*	3*c*, 3*c*, 3*c*, 3*c*, 5*c*	5
172	*A* ×	*Wa*	4*c*, 4*c*, 4*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	8
175	*A* ×	*W*	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	7
176	*A* ×	*W*	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	7
179	*A* ×	*Wa*	3*c*, 3*c*, 3*c*, 3*c*, 5*c*, 5*c*, 5*c*, 5*c*	8
184	*A* ×	*Wβ*	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	10
			Total	340

TABLE B.—*Offspring of Hybrids paired together.*

Catalogue Number	Parentage						Offspring	Number per Litter
	3	2	7	6	5	4		
H 7a	1c	2c	A ×	Wa	A ×	Wa	2fpw, 2ap, 2b	3
H 7β	,,	,,	,,	,,	,,	,,	2bp, 2c, 2d, 2d, 3c	5
H 8	2c	2c	A ×	Wa	A	Wa	3bp, 4ap, 4ap, 3c	4
H 9	2c	3c	A ×	Wa	A	Wa	3ap, 3b, 3b, 3cw, 3fp	5
H 18	3c	2c	A ×	Wa	A	Wa	3bpw, 3bp, 3c, A, A, A, A	7
H 19a	3c	3c	A ×	Wa	A	Wa	2c, 2c, 2cw, 4ew, A, A	6
H 19β	,,	,,	,,	,,	,,	,,	2e, 2bp	2
H 20	2c	2c	A ×	Wβ	A ×	Wa	2cw, 2e, 2fp, 3cw, Aw, A	6
H 29a	2c	3c	A ×	Wa	A ×	Wβ	2c, 2e, 3d, 4e, A	5
H 29β	,,	,,	,,	,,	,,	,,	2cw, 3fp, A	3
H 30	2c	5c	A ×	Wa	A	Wa	2dw, 2fp, 2fp, 3bp, 3d, 5cw	6
H 42a	5a	3c	A	Wa	A ×	Wa	4ap, 3c, 3c, Aw	4
H 42β	,,	,,	,,	,,	,,	,,	1cw, 3apw, 4a, 6a, A	5
H 61	5c	5c	A	W	A	Wa	5c, A	2
H 70	3d	2d	Wa	A	A	Wa	2c, 3a, 3e	3
H 71	4c	2d	A	W	A	Wa	3c, A	2
H 72	2d	2c	A	Wa	A	W	3c	1
H 73	5c	5c	A	W	Wa	A	3c, 5c, 5d	3
H 74	5c	5c	A	W	A	Wβ	3ap	1
H 76	2c	4c	A	W	A	Wβ	3e, A, A	3
H 77	3c	4c	A	W	A	Wβ	4e	1
*H 95	(?) c	(?) c	A	Wβ	A	Wβ	2e, 3e, 6bcp, 6bcp, Aw, A	6
H 96a	5a	5a	A	Wa	A	Wβ	5b, 5c, A, A	4
H 96β	,,	,,	,,	,,	,,	,,	5a, 5a, 5a, A	4
H 97a	5a	5a	A	Wa	A	Wa	5b	1
H 97β	,,	,,	,,	,,	,,	,,	3bp, 5bp, 5c, A	4
H 98a	5c	5d	A	Wa	A	Wa	4e, 4e, 6bp, 6c, 6c, 5c, A	7
H 98β	,,	,,	,,	,,	,,	,,	5bp, 5c, 5c, 6fp, A, A	6
H 99	5c	5c	Wβ	A	A	Wβ	5c, 5d, 6bp, A	4
H 100a	3c	3c	Wβ	A	A	Wa	2bp, 2c, 2d, 3d, 4bp, Aw	6
H 100β	,,	,,	,,	,,	,,	,,	3c, 4c, 4e, A, A, A	6
H 101a	6d	5c	A ×	Wa	A	Wβ	3e, 5e, 6e, 6fp, Aw	5
H 101β	,,	,,	,,	,,	,,	,,	6bfp, 6c, 6e, A, A, A	6
H 102a	5d	5d	A ×	Wa	A	Wa	1cw, 5bpw, 5dw, 5bc, 6e, Aw	6
H 102β	,,	,,	,,	,,	,,	,,	2bp, 3c, 6fp, 6fpw, 6fpw	5
H 103a	4d	4c	A ×	Wa	A ×	Wa	3bw, 3bpw, 4bc	3
H 103β	,,	,,	,,	,,	,,	,,	3b, 3bc, 3e, 4bc, 4bp, 4bp	6
H 104a	2c	3c	A ×	Wa	A ×	Wa	3bp, 2e, 2cw, A, A	5
H 104β	,,	,,	,,	,,	,,	,,	1cw, 2cw, 3bc, A	4
H 105a	3c	4c	A ×	Wa	A ×	Wa	2bp, 2c, 3bp, 3fp	4
H 105β	,,	,,	,,	,,	,,	,,	3bp, 3c, 4bp, 4bp, 4e, Aw	6
H 106a	3c	3c	A ×	Wa	A ×	Wa	3cw	1
H 106β	,,	,,	,,	,,	,,	,,	2fp, 3c, 3dw, A	4
H 107	4c	3c	A ×	Wβ	Wa	A	1bp, 4bc	2
H 108	2c	3c	A ×	Wa	A	Wβ	2e, 3bp, A, A, A	5
H 109a	3c	3c	A	Wβ	A	Wβ	2bpw, 2c, 3bpw, A, A, Aw	6
H 109β	,,	,,	,,	,,	,,	,,	2e, 3c, A, A, A	5
H 110	5c	5c	A	Wβ	A	Wβ	6apw, 6b	2
H 111a	5c	5c	A	W	A	Wβ	4bp, 4bpw, 5bpw, 5c, 6ap, 6c	6
H 111β	,,	,,	,,	,,	,,	,,	3bp, 3e, 5cw, 6e, 5g†, A, A	7
H 112a	3c	1c	A	W	A	W	1cw, 2cw, 2fp, A, A, A	6
H 112β	,,	,,	,,	,,	,,	,,	2c, 2bfp, A	3
H 113a	4c	3c	A	Wβ	A	Wa	3bcpw, 3cw, 3e, 4c, A	5
H 113β	,,	,,	,,	,,	,,	,,	1c, 2c, 3e, 4c, A, A	6
H 114	2c	2c	A ×	Wβ	A	Wβ	1bp, 1e, 2bp, 2bp, 2c, Aw	6
H 115a	4c	3c	A	W	Wβ	A	1c, 2ew, 3c, 4e, A	5
H 115β	,,	,,	,,	,,	,,	,,	3e, 4e, 4c, A	4
H 116a	4c	4c	A	W	A	Wβ	3bp, 4c, 4e, 4e, 4e, A	6
H 116β	,,	,,	,,	,,	,,	,,	3c, 4c, A	3
H 117a	5c	5c	A	Wβ	A	Wβ	5c, 6e, A	3
H 117β	,,	,,	,,	,,	,,	,,	3e, 5g, 3fp	3
H 118a	3c	2c	A	Wβ	A	Wa	2bp, 2cw, 3cw, 3c, 3e	5
H 118β	,,	,,	,,	,,	,,	,,	3bp, 3c, 3dw, 3e, A, A, A	7

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* A ♀ was accidentally fertilised by a ♂ from the same hybrid litter, before the sexes were separated.

† With dark red (not haemoglobin-coloured) eyes, classed as dark-eyed.

TABLE B.—(*continued.*)

Catalogue Number	Parentage						Offspring	Number per Litter
	3	2	7	6	5	4		
H 119a	5c	5c	A	Wβ	A	Wβ	2c, 3c, 5c, 6e, A, Aw	6
H 119β	"	"	"	"	"	"	A, A, A, A, A	5
H 120a	5c	5c	A	Wβ	Wa	A	5bpw, Aw	2
H 120β	"	"	"	"	"	"	4c, 4e, 5c, 5c, 5c, A	6
H 121a	4c	4c	Wa	A	A	Wβ	2apw, 2d, 3c, 4c, 4d, 4e, A	7
H 121β	"	"	"	"	"	"	3bp, 3c, 3cw, 4bp, 4bp, 4bp	6
H 122a	3c	3c	A	W	A	Wβ	2c, 2c, 3c, 3e, 3fp, 4e, A	7
H 122β	"	"	"	"	"	"	1c, 3ap, 3ap, 4c	4
H 123a	5c	5c	A	Wβ	A	Wβ	5c, 5c, A, A	4
H 123β	"	"	"	"	"	"	3c, 3e, 5c, 5bp, 6e, 6e	6
H 124a	5c	5c	A	Wa	A	Wβ	3e, 4c, 5bp, 5cw, 6e	5
H 124β	"	"	"	"	"	"	4e, 4e, 5bp, 5bp, A	5
H 125	5c	5c	A	Wβ	A ×	Wa	3c, 5bpw, 5bc, 5c, 5c, 5c, 6c	7
H 126a	2d	2c	A	Wa	A ×	Wβ	1cw, 1ew, 2bp, 2bp, 2c, 3c, A	7
H 126β	"	"	"	"	"	"	1ap, 2ew, 2e, 3ap, A	5
H 127a	5c	5c	A	Wβ	A ×	Wβ	5c, 5c, 5c, 5e, A	5
H 127β	"	"	"	"	"	"	5bpw, 5bp, 5bp, 3c, 6g	5
H 128a	5c	5c	A	Wβ	A	W	4afp, 4e, 5afp, 5cw, 6fpw, Aw, Aw	7
H 128β	"	"	"	"	"	"	5bp, A	2
H 129a	5c	5c	A	Wβ	A	W	5bp, 5c, 6e, 6fp	4
H 129β	"	"	"	"	"	"	2c, 4e, 5bpw, 5cw, 5e, 6ew	6
H 130	3c	3c	Wa	A	A	W	1cw, 3bpw, 4cw, A, A	5
H 133a	5c	5c	A ×	W	A ×	W	2e, A	2
H 133β	"	"	"	"	"	"	5c, 5c, 5c, A, A	5
H 134	3c	3c	A ×	W	A ×	W	A, A	2
H 135a	5c	5c	A ×	W	A ×	W	2e, 5bp, 6e, Aw	4
H 135β	"	"	"	"	"	"	5dw, A	2
H 136a	5a	5c	A	Wβ	A ×	W	2bp, 2c, 5a, 5a, 5cw	5
H 136β	"	"	"	"	"	"	4ap, 5bp, 6ap	3
H 137a	3c	4c	A ×	W	A ×	W	3g (eyes dark red, not blood-colour)	1
H 137β	"	"	"	"	"	"	3d, A, A	3
H 138a	5c	5c	A ×	W	Wa	A ×	3g, 5c, 5cw, Aw	4
H 138β	"	"	"	"	"	"	5bp, 5bpw, 5c, 6gw, A	5
H 139a	5e	3e	A	Wβ	Wa	A ×	1fp, 3fpw, A	3
H 139β	"	"	"	"	"	"	6e, A	2
H 142a	5c	5c	A	Wa	A	W	6e, A, A	3
H 142β	"	"	"	"	"	"	4c, 5c, 5c, 6e, 6fp	5
H 145a	2c	2c	A ×	Wβ	A ×	W	2c, A, A, A, Aw	5
H 145β	"	"	"	"	"	"	1c, 1fpw, 2c, 2bp	4
H 148a	5d	5c	A	Wa	A	W	5c, 5c, 5c, 6e, A, A	6
H 148β	"	"	"	"	"	"	4fp, 5c, A, A, Aw	5
H 150	4c	5c	A ×	W	A	Wa	4c, 4cw, 5c	3
H 201	5a	5a	A	Wa	A	Wβ	3a, 5a, 5a, 5a, A, A, Aw	7
H 202	5a	5a	A	Wa	A	Wβ	4ap, 5ap, A, A	4
H 210	5a	4c	A	Wβ	A	Wβ	4bp, A, A	3
H 224	3c	5c	A ×	W	A	Wa	1c, 2a, 2e, 3fp*, 3fp*, A	6
H 225	3c	3c	A ×	Wa	A	Wβ	2ap, 3fp, 3c, 3c, 4e, A, Aw	7
H 226	3c	4c	A	W	A ×	Wa	3bp, 3bpw, 4ew, A, A, A	6
H 227	4c	2c	A	W	A	Wβ	2cw, 2e, 3ew, 4bpw, 4bpw, 4fp	6
H 228	3c	4c	A ×	W	A ×	W	2c, 3c, 3d, A, A, Aw	6
H 229	2c	3c	A ×	Wβ	Wβ	A	2fp*, 2c, 2fpw, 3fpw, 3c, 4c	6
H 230	3c	3c	Wβ	A	Wa	A	4bp	1
H 231	3c	3c	A	W	A ×	Wa	3bc, 3c, 3c, 3d, 3e, 4e, A, A	8
H 232	3d	4c	Wa	A	A	Wβ	1bpw, 2bp, 3bp, 3c, 4e, A	6
H 233	3c	1c	A	Wβ	A	W	2c, 2c, 2c, 2c, 2c, 2c, 2ew, A, A	9
H 234	2e	5c	Wa	A	A	W	2fpw, 3c, 5cw, 6fp, 6fp	5
H 235	2c	5c	A	Wβ	A	Wβ	2c, 3e, 4dw, 5c, A, A	6
H 262	5d	2c	A	Wa	A	W	2bpw, 3bp, 3e, 5bp, 5c, A	6
							Total	555

* The record of eye-colour in these mice is uncertain.

TABLE C.—*Young Produced by pairing Hybrids and Albinos.*

Catalogue Number	Parentage						Coloured Young	Albinos	Number in Litter
	3	2	7	6	5	4			
H 1	A	3c	A	A	A ×	Wa	5c, 5c, 5c, 5c	—	4
H 2	A	3c	A	A	A ×	Wa	4d, 4d, 4e, 5d	5	9
H 3	A	2d	A	A	A ×	Wa	5c, 5c, 5c, 5c, 6c, 6d	4	10
H 4	A	5c	A	A	A	W	5c, 5d, 6e	2	5
H 5	A	5c	A	A	A	W	6c, 6d, 6d, 6d	1	5
H 6	A	5c	A	A	A	Wa	6d, 6d	2	4
H 11	A	3c	A	A	A	Wa	6e	5	6
H 12	3c	A	A	W	A	A	3c, 6e, 6e	2	5
H 13	5c	A	A	W	A	A	5d, 6e	1	3
H 14	5c	A	A	W	A	A	2e, 3e	4	6
H 15	A	5c	A	A	A	W	3a, 3a, 3e, 6a	4	8
H 16	A	5c	A	A	A	Wa	3e, 4g	5	7
H 17	A	5c	A	A	A	W	3d, 3e, 6d	2	5
H 24	A	5d	A	A	A	Wa	4d, 4d, 4d	3	6
H 26	A ×	3c	A (?)*	A (?)*	A	Wa	5d, 5d, 6e	1	4
H 27	3c	A	A	W	A	A	6e	5	6
H 28a	5c	A	A	Wa	A	A	5c, 5d	—	2
H 28β	"	"	"	"	"	"	5d, 6d	3	5
H 31	A	5c	A	A	A	Wa	— — —	1	1
H 32	2c	A	A	Wa	A	A	4c, 6c, 6c, 6e	3	7
H 33	A	5c	A	A	A	W	6e, 6e, 6e, 6e	4	8
H 34	3c	A	A ×	Wβ	A	A	5c, 5c, 6d	1	4
H 35	3c	A	A ×	Wβ	A	A	4d, 5d, 5d, 5d, 5d	1	6
H 38	2d	A	A	Wa	A	A	5d, 5d	2	4
H 39	2d	A	A	Wa	A	A	— — —	4	4
H 40	5a	A	A	Wa	A	A	6a, 6a	5	7
H 41	5c	A	A	Wa	A	A	5c, 6e	3	5
H 43	A	2c	A ×	Wa	A	A	5c, 6e, 6e	2	5
H 45	A ×	5c	A (?)†	A (?)†	A	W	6e	3	4
H 46	A	2c	A	A	A	Wa	3c, 3c, 3c	5	8
H 47	A ×	3c	A (?)†	A (?)†	A	Wa	6e, 6e	4	6
H 48	A	5c	A	A	A	Wa	6e	3	4
H 49a	A	5d	A	A	A	Wa	6e, 6g	3	5
H 49β	"	"	"	"	"	"	3c, 5d, 6e	2	5
H 51	A ×	5c	A (?)†	A (?)†	A	Wa	4c, 4c, 4e	1	4
H 52	A	3d	A	A	A	Wa	6e, 6e	3	5
H 55	2c	A	A ×	Wa	A	A	3a, 6g	4	6
H 56	2c	A	A ×	Wa	A	A	4c, 4e, 6d	1	4
H 57	A ×	5c	A (?)†	A (?)†	A	W	4c, 4c, 4c, 5d	3	7
H 58	2c	A ×	A ×	Wβ	A ×	A ×	2a	3	4
H 59	2c	A	A	Wa	A	A	5c, 6e	5	7
H 60	A	3c	A	A	A	Wa	4c, 4c, 6e, 6e	2	6
H 63	3c	A	A ×	Wa	A	A	2g, 5d, 6e	2	5
H 64	2c	A ×	A ×	Wa	A ×	A	2d, 2e	2	4
H 65	2e	A	Wa	A	A	A	6e	3	4
H 80	A	3c	A	A	A ×	Wa	5g, 6e	5	7
H 81	5c	A ×	A	Wβ	A	6e	3e, 4e, 6e, 6e, 6e	4	9
H 83	5e	A ×	A	Wβ	A	6e	4e, 5e, 5e, 6e	1	5
H 85	5c	A	A	Wβ	A	A	— — —	4	4
H 86	5c	A ×	A	Wβ	A	6e	5c, 5c	2	4
H 87	5c	A ×	A	Wβ	A	6e	6c, 6e	3	5
H 88a	A	3c	A ×	A ×	A	Wa	5c, 5c, 6e	3	6
H 88β	"	"	"	"	"	"	6e	5	6
H 92	A	5c	A	A	A	W	3c, 4e, 6e	3	6
H 131	A	2c	A	A	A	W	2e, 3c, 3c	1	4
H 140	5c	A	A ×	W	A	A	3c, 6c	4	6
H 143a	A	5c	A	A	A	W	5c, 6c, 6c	3	6
H 143β	"	"	"	"	"	"	4c, 5c	2	4
H 144a	A	4c	A	A	A ×	W	2e	1	2
H 144β	"	"	"	"	"	"	5c	3	4
H 146a	2c	A	A ×	Wβ	A	A	5c, 6c, 6e	3	6
H 146β	"	"	"	"	"	"	5c, 5c, 5c	2	5
H 147	3c	A	A ×	Wβ	A	A	3c	4	5
H 149a	5d	A	A	Wa	A	A	5c, 5c	4	6
H 149β	"	"	"	"	"	"	5d, 5d, 6d	3	6
H 151a	3c	A	A ×	W	A	A	5c, 5c, 6c, 6c	1	5
H 151β	"	"	"	"	"	"	5c, 6c	3	5

* Pedigree of these albinos uncertain.

† Pedigree unknown.

TABLE C.—(*continued.*)

Catalogue Number	Parentage						Coloured Young	Albinos	Number in Litter
	3	*2*	*7*	*6*	*5*	*4*			
H 152	3*c*	*A*	*A*	*W*	*A*	*A*	6*c*	5	6
H 153	3*c*	*A*	*A*	*W*	*A*	*A*	3*e*, 4*bc*	3	5
H 154	3*c*	*A*	*A*	*W*	*A*	*A*	5*bc*, 6*e*, 6*e*	2	5
H 155	2*c*	*A*	*A*	*Wβ*	*A*	*A*	4*c*, 4*c*, 5*c*, 6*e*	2	6
H 156	3*c*	*A*	*A*	*Wβ*	*A*	*A*	6*e*	3	4
H 157	5*a*	*A*	*A*	*Wβ*	*A*	*A*	5*a*, 5*a*, 5*d*	3	6
H 158$_\alpha$	5*a*	*A*	*A*	*Wβ*	*A*	*A*	5*c*, 5*c*, 5*c*	3	6
H 158$_\beta$	”	”	”	”	”	”	5*a*, 5*a*, 5*c*, 5*c*, 5*c*	1	6
H 159	5*a*	*A*	*A*	*Wβ*	*A*	*A*	5*c*	2	3
H 160	5*a*	*A*	*A*	*Wa*	*A* ×	*A*	5*c*, 5*c*, 5*c*, 5*c*	2	6
H 161	5*a*	*A*	*A*	*Wa*	*A*	*A*	5*a*, 5*c*, 5*c*	2	5
H 162	5*a*	*A*	*A*	*Wa*	*A* ×	*A*	5*a*, 5*c*	1	3
H 163	5*a*	*A*	*A*	*Wa*	*A*	*A*	5*a*, 5*b*, 4*c*, 4*c*	—	4
H 164$_\alpha$	*A*	4*c*	*A* ×	6*e*	*A* ×	*Wa*	5*c* (pale), 6*e*	1	3
H 164$_\beta$	”	”	”	”	”	”	6*e*, 6*e*	5	7
H 165	*A* ×	3*c*	*A* ×	6*e*	*A*	*Wβ*	5*c*	1	2
H 166	*A* ×	2*c*	*A* ×	6*e*	*A* ×	*Wa*	5*c*, 5*c*, 5*d*	5	8
H 167	*A* ×	5*c*	*A* ×	6*e*	*A*	*Wa*	5*d*, 6*c*, 6*c*, 6*d*, 6*e*	3	8
H 168	5*a*	*A* ×	*A*	*Wβ*	*A* ×	6*e*	4*a*, 5*a*, 5*a*, 6*c*	3	7
H 169	3*c*	*A* ×	*A* ×	*Wβ*	*A* ×	6*e*	4*c*, 5*c*, 5*c*, 6*c*, 6*e*	3	8
H 170	*A* ×	5*c*	6*g*	6*e*	*A*	*Wβ*	5*c* (pale), 5*c*, 6*g*	2	5
H 171	5*c*	*A* ×	*A* ×	*Wa*	6*g*	6*e*	6*c*, 6*c*, 6*c*	2	5
H 172	3*c*	*A* ×	*A* ×	*Wa*	*A* ×	6*e*	4*c*, 4*c*, 6*e*	2	5
H 173	5*c*	*A*	*A*	*Wβ*	*A*	*A*	5*c*, 6*e*, 6*e*	3	6
H 175	5*c*	*A*	*A*	*Wβ*	*A*	*A*	5*b*, 5*bc*, 5*c*, 5*d*, 4*e*	2	7
H 178	5*c*	*A*	*A* ×	*W*	*A*	*A*	3*c*, 5*c*, 5*c*	5	8
H 179	5*c*	*A*	*A*	*Wa*	*A*	*A*	5*c*, 5*c*, 5*c*, 5*d*, 6*d*	1	6
H 180	5*c*	*A*	*A*	*Wa*	*A*	*A*	5*c*, 5*c*, 5*c*, 5*c*, 6*c*	2	7
H 181	5*c*	*A*	*A* ×	*W*	*A*	*A*	5*c*, 5*e*, 6*e*	3	6
H 182	5*c*	*A*	*A*	*Wa*	*A*	*A*	5*c*, 5*c*, 6*e*	3	6
H 183	5*c*	*A*	*A*	*Wβ*	*A*	*A*	5*c*, 5*c*	4	6
H 184	5*c*	*A*	*A*	*Wβ*	*A*	*A*	6*e*	8	9
H 185	5*c*	*A*	*A*	*W*	*A*	*A*	4*e*, 5*c*, 6*e*, 6*e*, 6*e*, 6*e*, 6*e*	2	9
H 186	*A*	5*c*	*A* ×	*A*	*A*	*Wβ*	5*c*, 5*d*	6	8
H 188	*A*	5*c*	*A* ×	*A*	*Wa*	*A* ×	5*e*, 5*g*	—	2
H 189	*A*	5*c*	*A* ×	*A*	*A*	*Wβ*	6*c*, 3*e*, 2*d*, 6*e*	3	7
H 191	*A*	5*c*	*A*	*A*	*A*	*Wβ*	3*c*, 6*e*, 6*e*	2	5
H 192	*A*	5*c*	*A*	*A*	*A*	*Wβ*	5*c*, 5*c*, 5*d*, 4*e*, 6*e*	2	7
H 193	*A*	5*c*	*A*	*A*	*A* ×	*Wβ*	6*e*	1	2
H 194	*A*	5*d*	*A*	*A*	*A*	*Wa*	3*e*, 5*c*, 5*d*, 6*e*	5	9
H 195	*A*	5*c*	*A*	*A*	*A*	*Wβ*	5*c*, 5*c*, 5*c*, 5*d*, 6*e*	3	8
H 196	*A*	5*c*	*A*	*A*	*A*	*Wa*	6*d*, 6*d*, 6*d*, 6*d*	5	9
H 197	*A*	5*c*	*A*	*A*	*A* ×	*Wa*	5*c*, 5*c*	4	6
H 198	*A*	5*c*	*A*	*A*	*A*	*Wβ*	4*c*, 4*e*, 5*c*, 5*c*, 6*e*, 6*e*, 6*e*	2	9
H 199	*A*	5*c*	*A*	*A*	*A*	*Wβ*	4*e*, 5*c*	5	7
H 200	*A*	5*c*	*A*	*A* ×	*A* ×	*W*	3*bc*	4	5
H 203	5*a*	*A*	*A*	*Wa*	*A*	*A*	5*a*, 5*a*, 5*c*, 5*c*	2	6
H 204	5*a*	*A*	*A*	*Wa*	*A*	*A*	5*a*, 5*a*, 5*c*, 5*c*	3	7
H 205	5*a*	*A*	*A*	*Wa*	*A*	*A*	5*a*, 5*a*, 5*c*, 5*c*, 5*c*, 5*c*	—	6
H 206	*A*	5*c*	*A*	*A*	*A* ×	*W*	4*c*, 4*c*, 4*c*, 5*c*, 5*c*, 6*e*	3	9
H 207	*A*	5*c*	*A*	*A*	*A* ×	*W*	4*c*, 4*d*, 5*c*, 6*e*, 6*e*, 6*e*	3	9
H 208	5*c*	*A*	*A*	*Wβ*	*A*	*A*	4*c*, 6*g*	5	7
H 209	5*a*	*A*	*A*	*Wβ*	*A*	*A*	5*bc*	1	2
H 212	*A*	2*c*	*A* ×	*A*	*A* ×	*Wβ*	3*e*, 6*e*, 6*e*	4	7
H 213	*A*	3*c*	*A* ×	*A*	*A*	*Wβ*	3*bc*, 3*c*, 4*c*, 4*c*, 4*c*	2	7
H 214	*A*	3*c*	*A* ×	*Ap*	*Ap*	*Wa*	3*e*, 4*e*, 6*e*, 6*d*	4	8
H 216	*A*	3*c*	*A*	*A*	*A*	*Wβ*	3*g*, 4*e*	—	2
H 217	4*d*	*A*	*A* ×	*Wa*	*A* ×	*A*	3*bc*, 3*c*, 4*g*	3	6
H 218	2*c*	*A*	*A* ×	*Wβ*	*A* ×	*A*	3*bc*, 3*c*, 4*e*, 4*e*	3	7
H 219	5*d*	*A*	*A*	*Wa*	*A* ×	*A*	5*c*, 6*e*, 6*e*	3	6
H 220	2*c*	*A*	*A* ×	*Wa*	*A* ×	*A*	5*c*, 5*c*, 5*c*	2	5
H 222	4*c*	*A*	*A* ×	*W*	*A*	*A*	5*bc*, 5*bc*, 3*c*, 3*c*, 5*c*	4	9
H 223	2*c*	*A*	*A* ×	*Wβ*	*A*	*A*	4*g*, 5*c*	1	3
H 260	4*c*	*A* ×	*A* ×	*W*	6*e*	*A* ×	— — —	1	1
H 261	4*c*	*A*	*A* ×	*W*	6*e*	*A* ×	4*c*, 5*c*	5	7
								Total	746

TABLE D.

Results of mating Hybrids with "Extracted Albinos."

(*H* = *Hybrid*, *E* = *Extracted Albino*; *see text, p.* 25.)

Catalogue Number	Parents of Hybrid	Parents of Albino	Offspring	Number in Litter
G 1	*A* × *W*	*H* × *H*	3*ap*, 3*bp*, 5*aw*, *A*, *A*, *Aw*	6
G 2	*A* × *W*	*H* × *H*	1*bc*, 1*bc*, 3*c*, *A*	4
G 5	*A* × *W*	*H* × *H*	5*c*, 5*c*, 5*c*, 5*c*, *A*, *A*, *Aw*	7
G 6	*A* × *W*	*H* × *H*	2*c*, 3*c*, 3*c*, *A*, *A*, *A*	6
G 7	*A* × *W*	*H* × *H*	5*bp*, *A*, *A*, *A*, *Aw*	5
G 8	*A* × *W*	*H* × *H*	5*c*, 5*cw*, 6*e*, *A*, *A*	5
G 9	*A* × *W*	*H* × *H*	5*bp*, 5*c*, 5*c*, *A*, *A*	5
G 10	*A* × *W*	*H* × *H*	3*c*, 3*e*, 4*e*, *A*, *Aw*	5
G 11	*A* × *W*	*H* × *H*	5*cw*, *A*, *A*, *A*, *A*	5
G 3	*A* × *W*	*H* × *A*	*A*, *A*, *A*	3
G 4	*A* × *W*	*H* × *A*	5*a*, 5*a*, 5*aw*, 4*c*, *A*, *A*, *Aw*	7
G 22	*A* × *W*	*H* × *A*	5*c*, 5*c*, 6*e*, *A*	4
G 23	*A* × *W*	*H* × *A*	4*c*, 5*c*, *A*, *Aw*	4
G 24	*A* × *W*	*H* × *A*	5*c*, 6*e*, *A*, *A*	4
G 25	*A* × *W*	*H* × *A*	6*e*, 6*g*, *A*, *A*, *A*, *Aw*	6
G 26	*A* × *W*	*H* × *A*	2*c*, 3*c*, 5*c*, 6*e*, *A*, *A*, *A*	7
G 27	*A* × *W*	*H* × *A*	3*c*, 4*c*, 5*cw*	3
G 12	*E* × *W*	*H* × *A*	3*bp*, 3*d*, 3*gw*, *A*, *A*	5
G 14	*E* × *W*	*H* × *A*	4*c*, 5*c*, 5*c*, *A*, *A*	5
G 15	*E* × *W*	*H* × *A*	5*a*, *A*, *A*, *A*, *A*	5
G 16	*E* × *W*	*H* × *A*	5*a*, 5*a*, 5*a*, 5*a*, 3*e*, *A*, *Aw*	7
G 17	*E* × *W*	*H* × *A*	3*c*	1
G 19	*E* × *W*	*H* × *A*	3*e*, *A*, *A*, *A*, *A*	5
G 20	*E* × *W*	*H* × *A*	3*bp*, 3*bpw*, 5*c*, *A*, *A*, *A*	6
			Total	120

TABLE E.—*Result of pairing "Extracted Hybrids."*

	Catalogue Number	Parentage						Offspring	Number in Litter
		3	*2*	*7*	*6*	*5*	*4*		
Unions of Type *(H × H) × (H × H)*	2H 36	5b	3e	5a	5a	6d	5c	3a, 5a, 5c	3
	2H 39α	5c	1e	5c	5c	2c	2c	1c, 2c, 2c, 2c, 5c, 5bp, 5bp	7
	2H 39β	„	„	„	„	„	„	2c, 3c, 4c, 5bp, 5c	5
	2H 46	4d	5c	3c	4c	5c	5c	6bp	1
	2H 48	5a	1c	5a	5c	4c	3c	4ap, 5a, 5a, A, A	5
	2H 49	6e	3c	5c	5c	5c	5c	5d, 5d, 6e, 6e, 6e, 6e	6
	2H 50α	4e	3c	4c	3c	3c	4c	2c, 3c, 3c, 4e, A	5
	2H 50β	„	„	„	„	„	„	2c, 3e, 4e, 4e, A	5
	2H 51	4c	2c	4c	4c	3c	4c	1c, 3c, 3c, 3e, 3g	5
	2H 52	3c	5d	3c	5c	5c	5c	3c, 5c, 5c, 5bp, A	5
	2H 53α	5d	3c	6d	5c	3c	2c	3e, 3e, 4e, 4e, 5d, 6e, 6e, Aw	8
	2H 53β	„	„	„	„	„	„	3bp, 3c, 3c, 5cw, 6e	5
	2H 92	3e	4c	4c	3c	4c	5c	3c, 3cw, 4c	3
	2H 93	4e	4c	4c	3c	3c	5c	2fp, 3c, 3e, 4fp, A	5
	2H 96	6e	4c	5c	5c	4c	3c	3e, 3g, 5c, 5d, 5d, 6e, A	7
	2H 99	4bc	5c	4c	4c	5c	5c	4bc, 4bc, 5c, A, A	5
	2H 139	5a	6c	5a	5c	3c	5c	5a, 5b, 5cw, 6e, 6fpw	5
	2H 142	5c	5c	3c	5c	5d	5c	5bpw, 5bcp, 5bc, 5bc, 5c, 5c, 5c, 5cw	8
Unions of Type *(H × A) × (H × H)*	2H 23	5c	5c	5a	A	5d	5c	5bp, 5c, 5c, A, A	5
	2H 28	5d	4e	5a	A	3c	5c	5bp, 5c, 5c, 6e, 6e	5
	2H 29	6e	6c	3c	A	3c	5c	5c, 5c, 6e, A	4
	2H 32	6d	5c	A	2c	5a	5a	4c, 5c, 5c, 5c, 5c	5
	2H 33	5c	6b	A	2c	5a	5a	4bpw, 5b, 5b, 5c, 5c, 5cw	6
	2H 34	6d	3e	A	2c	5c	5c	3bp, 3c, 3c, 4c, 6e, 6e, A	7
	2H 38	6e	2c	2e	A	2c	2c	3bc, 3bpw, 5bp, 5bp, 5d, A	6
	2H 40	5c	3c	5c	5c	A	3c	5bc, 5bc, 5c	3
	2H 41	6e	6c	2e	A	5c	5c	3c, 6e, 6e, 6e, A	5
	2H 43	6e	3e	5c	A ×	4c	4c	3e, 3e, 3fp, 3fp, 4fp, 4e, 6e, 6e	8
	2H 44α	5c	2c	3c	A	3c	5c	3ap, 3c, 3c, 4c, 5bc, 5c, A	7
	2H 44β	„	„	„	„	„	„	2c, 5bc, 5c, A, A	5
	2H 100	5a	5d	5a	A ×	5c	5c	A, A, A	3
	2H 101	5a	6e	5a	A ×	5c	5c	5a, 6c, 6c, 6c, 6cw, A, A	7
	2H 103	5c	3e	5a	A	5c	5c	3c, 4e, 4e, 5c, 5c	5
	2H 106	5d	4e	A ×	3c	5d	5c	2e, 4d, A, A	4
	2H 107	6e	2c	A ×	3c	3c	2c	3c, 3c, 3fp, 3fp, 5bp, 5d	6
	2H 118	1c	6e	3c	4c	4c	A ×	3b, 5b, 5c, 5c, 5c	5
	2H 119	5c	6e	5c	5c	A ×	5c	4e, 5d, 6e, 6e, A, A	6
	2H 145	6e	5c	3c	A	5c	5c	3c, 4c, 5c, A, A	5
Unions of Type *(H × A) × (H × A)*	2H 18	6c	6e	3c	A	3c	A	6bcp, 6d, 6d, 6fp, A, A	6
	2H 19	6e	5c	3c	A	5a	A	3c, 3d, 5c, 5c, A	5
	2H 20	5c	5a	3c	A	5a	A	4a, 5a, 5a, 5d, 6d, A, A	7
	2H 22	5c	3e	3c	A	5c	A	4c, 4c, 5c, 5c, A	5
	2H 25	5c	6e	5a	A	A	3c	6e, A, A, A	4
	2H 26	5a	4c	5a	A	A	3c	3c, 4a, 4c, 5a, A, A	6
	2H 27	5a	6e	5a	A	A	3c	5bc, 5apw, 5a, 6ew, 3e	5
	2H 37	6e	3e	A ×	3c	A	3c	4e, 4e, 6e, A, A, A	6
	2H 45	5g	5c	A	3c	A	5c	4c, 5c, 5c, A, A, A	6
	2H 110	6e	5d	3c	A ×	5d	A	6d, 6d, 6dw	3
	2H 111	6c	5a	3c	A ×	5a	A	4a, 4a, 4e, 5bp	4
	2H 112	4c	5a	A	5c	5a	A	4a, 4e, 4e, 4e, 4d, 5a, 5a, 6e	8
	2H 113	6c	5c	3c	A	5a	A	3c, 5c, A, A, A	5
	2H 114	5d	6c	3c	A	3c	A ×	4d, 4d, 6d, 6e	4
	2H 115	5c	6d	3c	A	3c	A ×	4e, 4e, 5d, A	4
	2H 116	5d	5c	5d	A	3c	A ×	5bp, 5bp, 5bp, 5bp, A, A	6
	2H 143	6e	6e	2e	A	A	3c	2fpw, 3e, 6e, 6e, 6e, 6ew, 6fpw	7
	2H 144	5a	4g	5a	A	5c	A	3e, 4e, 6g, 6g, A, A	6
	2H 146	5c	5c	5a	A	A	5c	4bp, 5bp, 3c, 5c, 6e, 6fp, A	7
	2H 147	5a	6e	5a	A	5c	A	3a, 3ap, 5a, 6g, A, A, A, A	8
	2H 148	5c	5c	3c	A	5a	A	3c, 3c, 5c, 5c, 4bcp, 4bp, 4ap, 5ap, 5ap	9
								Total	321

TABLE F.

Result of mating "Extracted Hybrids" and "Extracted Albinos."

Catalogue Number	Parents of Albino	Parents of Hybrid	Offspring	Number in Litter
K 1	H × H	H × A	6e, 5d, 5d	3
K 2	H × A	H × H	4c, 5c, 5c, 5d, A	5
K 3	H × H	H × H	5c, 5c, 5c	3
K 4	H × H	H × H	5c, A, A, A	4
K 5	H × H	H × H	5c, 5c, 5c, A, A, Aw	6
K 6	H × H	H × H	5c, 5c, A, A, A, A, Aw	7
K 10	H × H	H × H*	3bpw, 4b, 4bpw	3
K 11	H × A	H × H	6bp, 6e, 6fp, A	4
K 12	H × H	H × A	3bc, 3c, 3c, A, A	5
K 15	H × H	H × H	3bp, 6bp, A, A, A	5
K 16	H × H	H × H	2e, 3e, 3e, 3c, 4c	5
K 19	H × A	H × H	3c, 4c, A	3
K 21	H × A	H × H	4e, 4e, 4e, 6d, 6e	5
K 23	H × H	H × A	4c, 5c, 5c, 5c, A, A, A, A	8
K 24	H × H	H × A	1e, 2c, 2c, A, A, A	6
K 27	H × A	H × H	6e, 6e, A, A, A	5
K 28	H × H	H × A	4c, 4c, 5c, 6g, A, A, A	7
K 29	H × A	H × H	2d, 3c, 3e, A, A, A	6
K 30	H × A	H × H	A	1
			Total	91

* The eyes of the hybrid used (the female) were possibly dark red, not black.

TABLE G.

Result of mating "Extracted Dominants" and Albinos. (E = "Extracted Albino.")

Catalogue Number	Parentage						Offspring	Number in Litter
	3	2	7	6	5	4		
2H 79	A	3bp	A	A	3c	2c	3c, 3c, 4c, 5c, 3e, 3e, 6e, 6e	8
2H 80	A	3fp	A	A	3c	4c	3e, 6e	2
2H 88	4bp	A	4c	3c	A	A	4bc, 4bc, 4bc, A	4
2H 90	5bp	E	5a	5a	5a	A	5b, 5c, 5c, 5c, 5c, 5c	6
2H 102	E	6bp	5a	A ×	5c	5c	5a, 5a, 5a, 5c, 5c, 6e, 6e	7
2H 104	E	2bp	A ×	3c	3c	3c	5c, 5cw	2
2H 105	E	2bp	A ×	3c	3c	3c	3c, 3c, 3c, 4c	4
2H 108	E	2fp	5c	A ×	6e	3e	3cw, 4e, 4e, 5c, 5c, 6e, 6e, 6e	8
2H 109	E	2bp	5c	A ×	4c	3c	4c, 4c, 4c, 4c, 4cw, 4e	6
2H 120	E	6bp	3c	A	5c	5c	5c, 5c, 5bp	3
2H 123	E	1bp	3c	A ×	5c	5d	2e, 4c, 4e, 5c, 5c, 6e	6
2H 124	4ap	E	3c	4c	3c	A	4cw, 6e, 6e, A, A	5
2H 125	E	3bp	5d	A	5c	5c	2c, 3bc, 4c, 5c, 5c, 5c	6
2H 126	4ap	E	5a	5c	4c	A ×	3c, 3c, 3c, 4a, 5d	5
2H 127	5bp	E	5a	5c	3c	A ×	5c, 5c, 4e, 6d, 6e	5
cr. 145	A	3bp	A	A	5a	3c	5b, 5b, 5b, 6b, 6b, 5c	6
cr. 146	—	—	—	—	—	—	4c, 5a, 5c, 5c, A, A, A, A	8
cr. 155	—	—	—	—	—	—	5a, A, A	3
cr. 156	—	—	—	—	—	—	5bc, A, A, A	4
							Total	98

TABLE H.

Result of pairing "Extracted Dominants."

Catalogue Number	Parentage						Offspring	Number in Litter
	3	*2*	*7*	*6*	*5*	*4*		
2H 11	*2bp*	*3ap*	*3c*	*3c*	*3d*	*2c*	*2bp*, *2bp*	2
2H 12	*5bp*	*4ap*	*5c*	*5c*	*5a*	*3c*	*2bp*, *4bp*, *5bp*, *5bp*, *5bcp*	5
2H 13	*6fp*	*3fp*	*5c*	*5c*	*3c*	*4c*	*6fp*, *6fp*, *6fp*, *6fp*	4
2H 15	*2bp*	*4bpw*	*5a*	*5c*	*5c*	*5c*	*3bp*, *3bp*, *3bp*, *4bp*, *A*	5
2H 55	*2bp*	*6bp*	*3c*	*2c*	*5c*	*5c*	*1ap*, *2ap*, *2ap*, *5ap*	4
2H 85	*3fp*	*3ap*	*5c*	*5c*	*5c*	*3c*	*3bp*, *3bp*, *3bp*, *3bp*, *3bp*, *3bp*	6
2H 135	*6fp*	*6bp*	*5c*	*5c*	*5c*	*5c*	*5bp*, *5bp*, *5bp*, *5bp*, *5bp*, *5bp*	6
							Total	32

APPENDIX II.

TABLES OF ORGANIC, FRATERNAL, AND ANCESTRAL CORRELATIONS.

TABLE I.

Organic Correlation: Whiteness and Coat-Colour in Hybrids.

Whiteness.

Coat-Colour.	*1*	*2*	*3*	*4*	5	*6*	Totals
a	—	—	—	—	12	—	12
c	4	28	57	37	164	2	292
d	—	9	3	1	11	2	26
e	—	2	4	1	3	—	10
Totals	4	39	64	39	190	4	340

TABLE II.

Fraternal Correlation in Whiteness among Hybrids.

First Brother.

Second Brother.	*1*	*2*	*3*	*4*	5	*6*	Totals
1	2	8	7	2	1	—	20
2	8	74	45	10	49	—	186
3	7	45	82	47	136	2	319
4	2	10	47	62	99	1	221
5	1	49	136	99	816	3	1104
6	—	—	2	1	3	—	6
Totals	20	186	319	221	1104	6	1856

TABLE III.

Fraternal Correlation in Colour among Hybrids.

First Brother.

		a	*c*	*d*	*e*	Totals
Second Brother.	*a*	42	26	25	—	93
	c	26	1522	28	12	1588
	d	25	28	66	15	134
	e	—	12	15	14	41
	Totals	93	1588	134	41	1856

TABLE IV.

Whiteness in Waltzing Parents and in Hybrids.

Hybrids.

		1	*2*	*3*	*4*	*5*	*6*	Totals
Waltzing Parents.	*a*	2	24	29	9	46	3	113
	β	—	8	14	12	62	1	97
	Totals	2	32	43	21	108	4	210

TABLE V.

Whiteness in Waltzing Parents and Colour in Hybrids.

Hybrids.

		a	*c*	*d*	*e*	Totals
Waltzing Parents.	*a*	7	76	25	5	113
	β	5	86	1	5	97
	Totals	12	162	26	10	210

TABLE VI.

Purity of Albino Parent and Whiteness in Hybrids.

Hybrids.

		1	*2*	*3*	*4*	*5*	*6*	Totals
Albino Parent.	Pure bred ...	2	21	34	23	129	3	212
	Cross bred ...	2	18	30	16	61	1	128
	Totals	4	39	64	39	190	4	340

TABLE VII.

Purity of Albino Parent and Colour of Hybrids.

Hybrids.

Albino Parent.	*a*	*c*	*d*	*e*	Totals
Pure bred ...	12	174	20	6	212
Cross bred ...	—	118	6	4	128
Totals	12	292	26	10	340

TABLE VIII.

Correlation in Coat-Colour between ♂ and ♀ Hybrids mated.

Male.

Female.	*a*	*c*	*d*	*e*	Totals
a	24	20	—	—	44
c	—	416	15	—	431
d	—	56	14	—	70
e	—	5	—	5	10
Totals	24	497	29	5	555

TABLE IX.

Correlation in Amount of Whiteness between ♂ and ♀ Hybrids mated.

Male.

Female.	*1*	*2*	*3*	*4*	*5*	*6*	Totals
1	—	8	—	—	—	—	8
2	—	38	33	3	17	—	91
3	18	22	70	33	6	—	149
4	—	8	22	31	3	—	64
5	—	6	14	3	203	—	226
6	—	—	—	—	11	—	11
Totals	18	82	139	70	240	—	549

TABLE X.

Organic Correlation between Whiteness and Coat-Colour in Offspring of Hybrids.

Amount of Whiteness.

Coat-Colour.	*1*	*2*	*3*	*4*	*5*	*6*	Totals
a	1	4	8	6	9	4	32
b	3	17	28	17	25	6	96
c	11	36	39	15	46	5	152
d	—	5	8	2	4	—	19
e	2	15	19	23	3	16	78
f	2	9	10	3	1	10	35
g	—	—	2	—	2	2	6
Totals	19	86	114	66	90	43	418

TABLE XI.

Organic Correlation between Coat-Colour and Waltzing in Offspring of Hybrids.

	A	*a*	*b*	*c*	*d*	*e*	*f*	*g*	Totals
Waltzing ...	20	3	20	30	6	8	9	1	97
Not	117	29	76	122	13	70	26	5	458
Totals	137	32	96	152	19	78	35	6	555

TABLE XII.

Organic Correlation between Amount of Whiteness in Coat and Waltzing in Offspring of Hybrids.

	A	*1*	*2*	*3*	*4*	*5*	*6*	Totals
Waltzing ...	20	9	18	19	8	17	6	97
Not	117	10	68	95	58	73	37	458
Totals	137	19	86	114	66	90	43	555

TABLE XIII.

Organic Correlation between Pinkness of Eye and Whiteness of Coat in Offspring of Hybrids.

	A	*1*	*2*	*3*	*4*	*5*	*6*	Totals
Pink-eyed ...	137	6	28	37	22	23	18	271
Not	—	13	58	77	44	67	25	284
Totals	137	19	86	114	66	90	43	555

TABLE XIV.

Organic Correlation between Pinkness of Eye and Coat-Colour in Offspring of Hybrids.

	A	*a*	*b*	*c*	*d*	*e*	*f*	*g*	Totals
Pink-eyed ...	137	19	80	—	—	—	35	—	271
Not	—	13	16	152	19	78	—	6	284
Totals	137	32	96	152	19	78	35	6	555

TABLE XV.

Organic Correlation between Pinkness of Eye and Waltzing in Offspring of Hybrids.

	A	Pink-eyed	Dark-eyed	Totals
Waltzing ...	20	36	41	97
Not	117	98	243	458
Totals	137	134	284	555

TABLE XVI.

Fraternal Correlation in Coat-Colour among Offspring of Hybrids.

First Brother.

Second Brother.

	A	*a*	*b*	*c*	*d*	*e*	*f*	*g*	Totals
A	262	45	141	297	29	153	50	10	987
a	45	50	29	54	4	15	7	1	205
b	141	29	174	185	26	111	32	11	709
c	297	54	185	308	37	185	70	14	1150
d	29	4	26	37	8	14	11	1	130
e	153	15	111	185	14	92	34	5	609
f	50	7	32	70	11	34	30	1	235
g	10	1	11	14	1	5	1	2	45
Totals	987	205	709	1150	130	609	235	45	4070

TABLE XVII.

Fraternal Correlation in Whiteness of Coat among Offspring of Hybrids.

First Brother.

Second Brother.

	A	*1*	*2*	*3*	*4*	*5*	*6*	Totals
A	262	38	163	190	97	154	83	987
1	38	10	42	29	11	3	6	139
2	163	42	204	126	59	29	15	638
3	190	29	126	220	134	60	34	793
4	97	11	59	134	108	59	29	497
5	154	3	29	60	59	246	115	666
6	83	6	15	34	29	115	68	350
Totals	987	139	638	793	497	666	350	4070

TABLE XVIII.

Fraternal Correlation in Eye-Colour among Offspring of Hybrids.

First Brother.

Second Brother.

	A	Pink-eyed	Dark-eyed	Totals
A	262	200	525	987
Pink-eyed ...	200	250	522	972
Dark-eyed ...	525	522	1064	2111
Totals	987	972	2111	4070

TABLE XIX.

Fraternal Correlation in Waltzing among Offspring of Hybrids.

First Brother.

		Waltzing	Not	Totals
Second Brother.	Waltzing ...	124	566	690
	Not... ...	566	2814	3380
	Totals	690	3380	4070

TABLE XX.

Correlation between Coat-Colour in the Offspring of Hybrids and Purity of Albino Grandparents.

Coat-Colour in Young.

		A	*a*	*b*	*c*	*d*	*e*	*f*	*g*	Totals
Purity of Albino Grandparents.	Both Pure-bred	80	16	46	89	8	50	14	2	305
	One Cross-bred	30	15	29	39	4	19	15	1	152
	Both Cross-bred	27	1	21	24	7	9	6	3	98
	Totals	137	32	96	152	19	78	35	6	555

TABLE XXI.

Correlation between Whiteness in Coat among Offspring of Hybrids and Purity of Albino Grandparents.

Whiteness in Young.

		A	*1*	*2*	*3*	*4*	*5*	*6*	Totals
Purity of Albino Grandparents.	Both Pure-bred	80	6	35	54	45	58	27	305
	One Cross-bred	30	10	26	37	13	22	14	152
	Both Cross-bred	27	3	25	23	8	10	2	98
	Totals	137	19	86	114	66	90	43	555

TABLE XXII.

Correlation between Pinkness of Eye in Offspring of Hybrids and Purity of Albino Grandparents.

Eye-Colour in Young.

		A	Pink-eyed	Dark-eyed	Totals
Purity of Albino Grandparents.	Both Pure-bred ...	80	65	160	305
	One Cross-bred ...	30	48	74	152
	Both Cross-bred ...	27	21	50	98
	Totals	137	134	284	555

TABLE XXIII.

Correlation between Waltzing in Offspring of Hybrids and Purity of Albino Grandparents.

Waltzing in Young.

		Waltzing	Normal	Totals
Purity of Albino Grandparents.	Both Pure-bred ...	45	260	305
	One Cross-bred ...	30	122	152
	Both Cross-bred ...	22	76	98
	Totals	97	458	555

TABLE XXIV.

Correlation between Whiteness in Offspring of Hybrids and in Waltzing Grandparents.

Whiteness in Young.

		A	*1*	*2*	*3*	*4*	*5*	*6*	Totals
Whiteness in Waltzing Grandparents.	$\alpha+\alpha$	18	3	23	34	14	11	9	112
	$\alpha+\beta$	40	7	22	33	22	23	8	155
	$\beta+\beta$	25	2	12	12	3	17	10	81
	Totals	83	12	57	79	39	51	27	348

TABLE XXV.

Correlation between Coat-Colour in Offspring of Hybrids and Whiteness in Waltzing Grandparents.

Coat-Colour in Young.

		A	*a*	*b*	*c*	*d*	*e*	*f*	*g*	Totals
Whiteness in Waltzing Grandparents.	$\alpha+\alpha$	18	9	32	28	6	9	10	—	112
	$\alpha+\beta$	40	13	26	39	6	25	6	—	155
	$\beta+\beta$	25	1	14	21	2	12	4	2	81
	Totals	83	23	72	88	14	46	20	2	348

TABLE XXVI.

Correlation between Eye-Colour in Offspring of Hybrids and Whiteness in Waltzing Grandparents.

Eye-Colour in Young.

		A	Pink-eyed	Dark-eyed	Totals
Whiteness in Waltzing Grandparents.	$\alpha+\alpha$	18	37	57	112
	$\alpha+\beta$	40	35	80	155
	$\beta+\beta$	25	18	38	81
	Totals	83	90	175	348

TABLE XXVII.

Correlation between Waltzing in Offspring of Hybrids and Whiteness in Waltzing Grandparents.

Waltzing in Young.

Whiteness in Waltzing Grandparents.	Waltzing	Normal	Totals
$\alpha+\alpha$	24	88	112
$\alpha+\beta$	24	131	155
$\beta+\beta$	11	70	81
Totals	59	289	348

TABLE XXVIII.

Correlation between Whiteness of Coat in Offspring of Hybrids and Whiteness of Coat in Hybrid Father.

Whiteness in Offspring.

Whiteness in Hybrid Father.	*A*	*1*	*2*	*3*	*4*	*5*	*6*	Totals
1	6	1	11	—	—	—	—	18
2	18	7	27	23	5	2	—	82
3	39	8	27	43	20	—	2	139
4	17	1	6	24	22	—	—	70
5	55	2	14	23	19	88	39	240
Totals	135	19	85	113	66	90	41	549

TABLE XXIX.

Correlation between Colour of Coat in Offspring of Hybrids and Whiteness in Hybrid Father.

Coat-Colour in Young.

Whiteness in Hybrid Father.	*A*	*a*	*b*	*c*	*d*	*e*	*f*	*g*	Totals
1	6	—	1	9	—	1	1	—	18
2	18	6	18	22	3	11	4	—	82
3	39	8	16	41	5	20	10	—	139
4	17	1	24	12	4	10	1	1	70
5	55	17	35	68	7	34	19	5	240
Totals	135	32	94	152	19	76	35	6	549

TABLE XXX.

Correlation between Pinkness of Eye in Offspring of Hybrids and Whiteness in Hybrid Father.

Whiteness in Father.

Eye-Colour in Young.	*1*	*2*	*3*	*4*	*5*	Totals
Albino ...	6	18	39	17	55	135
Pink-eyed	2	26	27	21	56	132
Dark-eyed	10	38	73	32	129	282
Totals	18	82	139	70	240	549

TABLE XXXI.

Correlation between Waltzing in Offspring of Hybrids and Whiteness in Hybrid Father.

Whiteness in Father.

Waltzing in Young.	*1*	*2*	*3*	*4*	*5*	Totals
Waltzing ...	3	19	26	9	39	96
Normal ...	15	63	113	61	201	453
Totals	18	82	139	70	240	549

TABLE XXXII.

Correlation between Coat-Colour in Offspring of Hybrids and Coat-Colour in Hybrid Father.

Coat-Colour in Young.

Coat-Colour in Father.	*A*	*a*	*b*	*c*	*d*	*e*	*f*	*g*	Totals
a	9	9	4	2	—	—	—	—	24
c	121	22	87	141	18	73	29	6	497
d	5	1	5	9	1	4	4	—	29
e	2	—	—	—	—	1	2	—	5
Totals	137	32	96	152	19	78	35	6	555

TABLE XXXIII.

Correlation between Whiteness in Offspring of Hybrids and Coat-Colour in Hybrid Father.

Whiteness in Young.

Coat-Colour in Father.	*A*	*1*	*2*	*3*	*4*	*5*	*6*	Totals
a	9	—	—	2	1	12	—	24
c	121	17	84	107	63	71	34	497
d	5	1	2	4	2	7	8	29
e	2	1	—	1	—	—	1	5
Totals	137	19	86	114	66	90	43	555

TABLE XXXIV.

Correlation between Eye-Colour in Offspring of Hybrids and Coat-Colour in Hybrid Father.

Coat-Colour in Father.

Eye-colour in Young.	*a*	*c*	*d*	*e*	Totals
Albino ...	9	121	5	2	137
Pink-eyed ...	4	120	8	2	134
Dark-eyed ...	11	256	16	1	284
Totals	24	497	29	5	555

TABLE XXXV.

Correlation between Waltzing in Offspring of Hybrids and Coat-Colour in Hybrid Father.

Coat-Colour in Father.

Waltzing in Young.	*a*	*c*	*d*	*e*	Totals
Waltzing ...	1	89	6	1	97
Normal ...	23	408	23	4	458
Totals	24	497	29	5	555

TABLE XXXVI.

Correlation between Colour of Coat in Offspring of Hybrids and Whiteness in Hybrid Mother.

Coat-Colour in Young.

Whiteness in Mother.	*A*	*a*	*b*	*c*	*d*	*e*	*f*	*g*	Totals
1	—	1	2	2	2	—	1	—	8
2	21	5	13	25	4	11	12	—	91
3	46	5	23	42	7	18	7	1	149
4	9	1	18	20	2	13	1	—	64
5	55	20	37	62	4	30	13	5	226
6	4	—	1	1	—	4	1	—	11
Totals	135	32	94	152	19	76	35	6	549

TABLE XXXVII.

Correlation between Whiteness of Coat in Offspring of Hybrids and Whiteness of Coat in Hybrid Mother.

Whiteness in Young.

Whiteness in Mother.	*A*	*1*	*2*	*3*	*4*	*5*	*6*	Totals
1	—	—	7	1	—	—	—	8
2	21	8	29	23	5	3	2	91
3	46	5	35	47	16	—	—	149
4	9	3	6	19	26	1	—	64
5	55	3	8	22	19	85	34	226
6	4	—	—	1	—	1	5	11
Totals	135	19	85	113	66	90	41	549

TABLE XXXVIII.

Correlation between Eye-Colour in Offspring of Hybrid and Whiteness in Hybrid Mother.

Whiteness in Mother.

Eye-Colour in Young.	*1*	*2*	*3*	*4*	*5*	*6*	Totals
Albino ...	—	21	46	9	55	4	135
Pink-eyed ...	3	27	32	14	54	2	132
Dark-eyed ...	5	43	71	41	117	5	282
Totals	8	91	149	64	226	11	549

TABLE XXXIX.

Correlation between Waltzing in Offspring of Hybrids and Whiteness in Hybrid Mother.

Whiteness in Mother.

Waltzing in Young.	*1*	*2*	*3*	*4*	*5*	*6*	Totals
Waltzing ...	1	21	24	12	37	1	96
Normal ...	7	70	125	52	189	10	453
Totals	8	91	149	64	226	11	549

TABLE XL.

Correlation between Coat-Colour in Offspring of Hybrids and Coat-Colour in Hybrid Mother.

Coat-Colour in Young.

Coat-Colour in Mother.	*A*	*a*	*b*	*c*	*d*	*e*	*f*	*g*	Totals
a	13	17	7	7	—	—	—	—	44
c	108	12	70	129	18	64	24	6	431
d	14	3	19	14	1	13	6	—	70
e	2	—	—	2	—	1	5	—	10
Totals	137	32	96	152	19	78	35	6	555

TABLE XLI.

Correlation between Whiteness of Coat in Offspring of Hybrids and Coat-Colour in Hybrid Mother.

Whiteness in Young.

Coat-Colour in Mother.	*A*	*1*	*2*	*3*	*4*	*5*	*6*	Totals
a	13	1	2	5	5	16	2	44
c	108	12	74	91	55	63	28	431
d	14	5	9	16	6	10	10	70
e	2	1	1	2	—	1	3	10
Totals	139	19	86	114	66	90	43	555

TABLE XLII.

Correlation between Eye-Colour in Offspring of Hybrids and Coat-Colour in Hybrid Mother.

Coat-Colour in Mother.

Eye-Colour in Young.	*a*	*c*	*d*	*e*	Totals
Albino ...	13	108	14	2	137
Pink-eyed ...	11	97	21	5	134
Dark-eyed ...	20	226	35	3	284
Totals	44	431	70	10	555

TABLE XLIII.

Correlation between Waltzing in Offspring of Hybrids and Coat-Colour in Hybrid Mother.

Coat-Colour in Mother.

Waltzing in Young.		*a*	*c*	*d*	*e*	Totals
	Waltzing ...	5	74	15	3	97
	Normal ...	39	357	55	7	458
	Totals	44	431	70	10	555

TABLE XLIV.

Organic Correlation between Coat-Colour and Whiteness in Offspring of Hybrids and Albinos.

Coat-Colour.

Amount of Whiteness.		*A*	*a*	*b*	*c*	*d*	*e*	*g*	Totals
	A	368	—	—	—	—	—	—	368
	1	—	—	—	—	—	—	—	—
	2	—	1	—	—	2	4	1	8
	3	—	3	4	17	1	10	1	36
	4	—	1	1	27	7	15	3	54
	5	—	15	7	101	27	4	2	156
	6	—	3	—	22	18	77	4	124
	Totals	368	23	12	167	55	110	11	746

TABLE XLV.

Correlation between Whiteness of Coat in Offspring of Hybrids × Albinos and the Purity of their Albino Grandparents. (A = Pure-bred Albino; A × = Cross-bred Albino. All four Grandparents are indicated, each pair in one bracket.)

Coat-Colour in Young.

Degree of Purity in Grandparents.		*A*	*1*	*2*	*3*	*4*	*5*	*6*	Totals
	(*A* . *A*) (*A* . *W*) ...	193	—	2	19	22	81	68	385
	(*A* . *A*) (*A* × . *W*)...	70	—	2	6	12	39	21	150
	(*A* . *A* ×) (*A* . *W*) ...	31	—	1	5	6	13	12	68
	(*A* . *A* ×) (*A* × . *W*)...	18	—	2	6	3	5	2	36
	(*A* × . *A* ×) (*A* . *W*) ...	17	—	—	—	1	8	8	34
	(*A* × . *A* ×) (*A* × . *W*)...	27	—	1	—	4	7	9	48
	Totals ...	356	—	8	36	48	153	120	721

TABLE XLVI.

Correlation between Coat-Colour in Offspring of Hybrid × Albino and the Purity of their Albino Grandparents. (The Grandparents indicated as in the preceding Table.)

Coat-Colour in Young.

Degree of Purity in Grandparents.		*A*	*a*	*b*	*c*	*d*	*e*	*g*	Totals
	(*A* . *A*) (*A* . *W*) ...	193	17	6	75	32	58	4	385
	(*A* . *A*) (*A* × . *W*) ...	70	1	2	45	13	15	4	150
	(*A* . *A* ×) (*A* . *W*) ...	31	1	1	15	3	17	—	68
	(*A* . *A* ×) (*A* × . *W*) ...	18	—	3	5	1	7	2	36
	(*A* × . *A* ×) (*A* . *W*) ...	17	3	—	8	2	3	1	34
	(*A* × . *A* ×) (*A* × . *W*) ...	27	1	—	14	1	5	—	48
	Totals ...	356	23	12	162	52	105	11	721

TABLE XLVII.

Correlation between Whiteness in Offspring of Hybrid × Albino and Whiteness in Waltzing Grandparent.

Whiteness in Young.

Whiteness in Waltzing Grandparent.		*A*	*1*	*2*	*3*	*4*	*5*	*6*	Totals
	α	168	—	3	10	21	78	57	337
	β	108	—	2	10	20	55	31	226
	Totals	276	—	5	20	41	133	88	563

TABLE XLVIII.

Correlation between Coat-Colour in Offspring of Hybrid × Albino and Whiteness in Waltzing Grandparent.

Coat-Colour in Young.

Whiteness in Waltzing Grandparent.		*A*	*a*	*b*	*c*	*d*	*e*	*g*	Totals
	α	168	12	2	74	34	40	7	337
	β	108	8	5	52	12	37	4	226
	Totals	276	20	7	126	46	77	11	563

TABLE XLIX.

Correlation between Coat-Colour in Offspring of Hybrid × Albino and Purity of Albino Parent.

Coat-Colour in Young.

Purity of Albino Parent.		*A*	*a*	*b*	*c*	*d*	*e*	*g*	Totals
	Pure-bred ...	319	19	12	142	48	91	10	641
	Cross-bred ...	49	4	—	25	7	19	1	105
	Totals	368	23	12	167	55	110	11	746

TABLE L.

Whiteness of Coat in Offspring of Hybrid × Albino and Purity of Albino Parent.

Whiteness in Young.

Purity of Albino Parent.		*A*	*1*	*2*	*3*	*4*	*5*	*6*	Totals
	Pure-bred ...	319	—	5	35	42	138	102	641
	Cross-bred ...	49	—	3	1	12	18	22	105
	Totals	368	—	8	36	54	156	124	746

TABLE LI.

Whiteness in Offspring of Hybrid × Albino and Whiteness in Hybrid Parent.

Whiteness in Young.

Whiteness in Hybrid Parent.		*A*	*1*	*2*	*3*	*4*	*5*	*6*	Totals
	2	61	—	4	9	8	20	16	118
	3	77	—	1	7	15	24	28	152
	4	23	—	1	4	2	6	3	39
	5	207	—	2	16	29	106	77	437
	Totals	368	—	8	36	54	156	124	746

TABLE LII.

Coat-Colour in Offspring of Hybrid × Albino and Whiteness in Hybrid Parent.

Coat-Colour in Young.

Whiteness in Hybrid Parent.		*A*	*a*	*b*	*c*	*d*	*e*	*g*	Totals
	2	61	2	1	31	6	15	2	118
	3	77	—	3	30	13	26	3	152
	4	23	—	3	8	—	4	1	39
	5	207	21	5	98	36	65	5	437
	Totals	368	23	12	167	55	110	11	746

TABLE LIII.

Whiteness in Offspring of Hybrid × Albino and Coat-Colour in Hybrid Parent.

Whiteness in Young.

Coat-Colour in Mother.		*A*	*1*	*2*	*3*	*4*	*5*	*6*	Totals
	a	28	—	—	—	3	40	3	74
	c	297	—	8	32	46	100	108	591
	d	39	—	—	4	4	14	11	72
	e	4	—	—	—	1	2	2	9
	Totals	368	—	8	36	54	156	124	746

TABLE LIV.

Coat-Colour in Offspring of Hybrid × Albino and in Hybrid Parent.

Coat-Colour in Young.

Coat-Colour in Mother.	*A*	*a*	*b*	*c*	*d*	*e*	*g*	Totals
a	28	18	2	25	1	—	—	74
c	297	5	9	131	43	97	9	591
d	39	—	1	11	11	8	2	72
e	4	—	—	—	—	5	—	9
Totals	368	23	12	167	55	110	11	746

APPENDIX III.

Note on the Absence of anything like Telegony in the Albino Mice used.

It is well known that albino mice, paired together, breed true in coat-colour and in eye-colour. The following table, in which the notation is the same as that used in the previous part of the present paper, records a fairly long series of cases in which a female albino mouse was mated, first with a coloured mouse of some kind, and afterwards with an albino. The table shows clearly enough that in no single case did an albino doe, which had previously produced coloured young by a coloured buck, fail to produce a truly albino litter when subsequently mated with an albino buck.

I. First Non-Albino Mating		II. Albino Mating
Type of Buck	Offspring	Offspring
Japanese Waltzing mouse	2*c*, 2*d*, 2*d*, 3*d*, 5*d*, 5*d*	4 alb.
Waltzer	2*c*, 2*c*, 2*c*, 2*c*, 2*c*, 2*d*	3 alb.
Waltzer	2*c*, 2*d*, 3*d*, 3*d*, 4*d*, 4*d*	(i) 1 alb. (ii) 5 alb.
Waltzer	3*c*, 3*c*, 5*c*, 5*c*, 5*c*, 5*c*	4 alb.
Waltzer	3*c*, 4*c*, 4*c*, 4*c*, 4*c*, 4*c*, 4*c*	2 alb.
Waltzer	1*c*, 2*c*, 2*c*, 3*c*, 4*c*	3 alb.
Waltzer	4*c*, 4*c*, 4*e*, 5*c*, 5*c*, 5*c*, 5*c*, 5*e*	7 alb.
Normal chocolate mouse	6*e*, 6*e*, 6*e*, 6*g*, 6*g*	6 alb.
Hybrid (5*c*) ...	5*c*, 5*d*, 6*e* & 2 alb.	8 alb.
Hybrid (5*c*) ...	6*d*, 6*d* & 2 alb.	2 alb.
Hybrid (5*c*) ...	6*d*, 6*d*, 6*d*, 6*c* & 1 alb.	3 alb.
Waltzer	All still-born	5 alb.
Hybrid (3*c*) ...	4*e*, 4*d*, 4*d*, 5*d* & 5 alb.	5 alb.
Hybrid (3*c*) ...	6*e* & 5 alb.	3 alb.
Hybrid (3*c*) ...	4*d*, 4*d*, 4*d* & 3 alb.	4 alb.
Waltzer	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 2*c*, 3*c*, 3*c*, 3*c*	5 alb.
Waltzer	5*c*, 5*c*, 5*c*, 5*c*, 2*c*, 3*c*, 4*c*	5 alb.
Hybrid (2*c*) ...	6*e*, 6*e* & 3 alb.	1 alb.
Black mouse ...	6*e*, 3*e* & 6 alb.	6 alb.
Waltzer	3*c*, 5*c*, 5*c*, 5*c*	2 alb.
Waltzer	5*c*, 5*c*, 5*c*, 2*c*, 2*c*, 2*c*	6 alb.
"Extracted Dominant" 3*a* (*pw*) ...	5*a* & 2 alb.	8 alb.
" ...	5*b*, 5*b*, 5*b*, 5*b*, 6*b*, 6*b* & 1 alb.	9 alb.
"Extracted Dominant" 3*a* (*pw*) ...	5*a*, 5*c*, 5*c*, 4*c* & 4 alb.	8 alb.
Waltzer	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	6 alb.
"Extracted Dominant" 3*a* (*pw*) ...	5*bc* & 3 alb.	7 alb.
Waltzer	2*c*, 2*c*, 3*c*, 5*c*, 5*c*, 5*c*, 5*c*	8 alb.
Waltzer	2*c*, 2*c*, 2*c*, 2*c*, 3*c*	5 alb.
Waltzer	6*c*, 5*d*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	1 alb.
Waltzer	3*c*, 3*c*, 3*c*, 2*c*, 2*c*, 2*c*	8 alb.
Waltzer	5*c*, 5*c*, 2*c*, 2*c*, 2*c*, 3*c*	6 alb.
Waltzer	3*c*, 3*b* (*p*)	3 alb.
Black-eyed Fawn	6*a*, 6*a*, 6*a*, 6*e*, 6*g*	8 alb.
Hybrid (5*c*) ...	5*c* (very pale), 5*c*, 6*g* & 2 alb.	5 alb.
Hybrid (2*c*) ...	5*c*, 5*d*, 5*c* & 5 alb.	8 alb.
Hybrid (3*c*) ...	6*c*, 6*e*, 6*c*, 5*d*, 6*d* & 3 alb.	7 alb.
Black mouse ...	6*c* & 1 alb.	4 alb.
Waltzer	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 4*c*	7 alb.
Waltzer	5*c*, 5*c*, 5*c*, 5*c*, 5*c*	4 alb.
Waltzer	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	7 alb.
Waltzer	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	7 alb.
Waltzer	5*c*, 5*c*, 5*c*, 5*c*, 5*c*, 5*c*	7 alb.
Hybrid (3*c*) ...	5*c* & 1 alb.	7 alb.
Waltzer	3*c*, 3*c* (*w*), 3*c* (*w*), 4*c*	8 alb.
Waltzer	5*c*, 3*c*, 3*c*, 3*c*, 3*c*	7 alb.
Waltzer	5*c*, 5*c*, 4*c*, 3*c*, 3*c*	7 alb.
Waltzer	5*c*, 5*c*, 5*c*, 5*c*, 5*c*	8 alb.

GRADUATION OF A SICKNESS TABLE BY MAKEHAM'S HYPOTHESIS.

By JOHN SPENCER, *Actuary.*

Some time ago an examination of certain sickness tables suggested to me the possibility that for a considerable period of life a law analogous to the well-known law of Mortality of Makeham might be found to apply to Sickness, i.e., that the force of sickness at any age x or the proportion of persons sick out of the number living at the precise moment of attaining that age might admit of being expressed in the form $A + Bc^x$, and I made various experiments to test the theory. Since that time Mr W. Palin Elderton, who had also investigated the same point, has referred to the matter in *Biometrika**, and in a paper read in September, 1903, before the International Congress of Actuaries in New York, and has given the values of $\log_{10} c$ deduced by him from various sickness experiences.

The idea of a mathematical law governing Sickness is by no means a novel one. In a paper submitted to the International Statistical Congress in 1860† Gompertz suggested that for ages between 20 and 60, S_x, the rate of sickness at age x or the average number of weeks' sickness experienced during a year by persons of that age, might be written kg^{c^x}, from which would follow the relation

$$\log S_x = A_1 + B_1 c_1^x.$$

Again Makeham himself dealt with the subject in 1871 when he read a paper "On the laws of Sickness and Invalidism" before the Institute of Actuaries‡. He concluded from his investigation of data then available that the quantity h_x consisting of the number of healthy, as distinct from sick, persons aged x out of l_x the number living on the usual form of mortality table, was a function of the form $ks^x g^{c^x}$, this being the shape assumed by the l_x column when Makeham's law of mortality applies. This theory of Makeham's regarding sickness possesses one or two advantages of some importance and it differs from the other hypotheses mentioned above in introducing the element of mortality. It gives $\left(1-\frac{h_x}{l_x}\right)$ as the force of sickness at age x and leads to the result

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* Vol. II. p. 504.

† Reprinted in *Journal of Institute of Actuaries*, Vol. XVI. p. 329. See also *Phil. Trans.* Vol. 152, p. 554.

‡ *J. I. A.* Vol. XVI. p. 408.

$$\text{colog}\left(\frac{h_{x+1}}{h_x}\right)=A_2+B_2c_2^{\,x}.$$

The material which formed the subject of my investigation is embodied in Mr A. W. Watson's important work on the Sickness and Mortality Experience of the Manchester Unity Friendly Society for the five years 1893–1897*. The magnitude of the data there dealt with—embracing as they do no fewer than 39,000 deaths in the quinquennium and the record of upwards of 7,000,000 weeks of sickness—and the care and accuracy with which the observations have been analyzed and tabulated entitle the results disclosed in the volume to a degree of authority to which no previous investigation of the same character can lay claim. Mr Watson's exhaustive enquiry led him to deal with his voluminous data upon novel lines, and we find tabulated the mortality experience of various sections of the Society grouped according to geographical situation, while as regards Sickness the element of occupation was the factor which determined the classification, the experience of each of the four following groups of trades being published:—

(*a*) Agricultural and General (Normal) occupations;

(*b*) Building Trades, Railway, Seafaring and Outdoor Labouring Occupations;

(*c*) Quarry Workers, Iron, Steel and Chemical Workers, &c.; and

(*d*) Mining Occupations.

The first of these groups is the one to which the following notes relate. It consists, broadly speaking, of persons engaged in occupations involving no special hazard, and comprises nearly 80 per cent. of the membership of the Society. These lives were during the quinquennium exposed to risk of sickness for 2,352,099 years, while they experienced in the aggregate 5,289,586 weeks of sickness in the period.

Throughout the investigation in determining the quantity "Exposed to Risk of Sickness" it was assumed, with a particular object in view, that lives dying in any calendar year during the period of observation were at risk until the middle of the year. In consequence of this assumption the ungraduated rates of sickness which were obtained by dividing the number of weeks' sickness experienced during the year by persons of a particular age by the quantity "Exposed to Risk" at that age differ from the rates of sickness ordinarily tabulated. They represent rather what might be termed central rates of sickness, or, approximately speaking, values of the force of sickness at the middle of the year. The latter consideration enables us on the hypothesis which I am discussing to write the tabulated rate of sickness in the form $A+Bc^{x+\frac{1}{2}}$ and suggests a simple method of deducing the values of the constants. Having for reasons which will appear presently come to the conclusion that a Makeham curve* would not apply throughout the whole of the table, i.e., from age 16 to 100, I ultimately divided the data for ages 19—78 into three groups consisting respectively of ages 19—38, 39—58, and 59—78. The ungraduated rates in each of these groups were summed, the resulting totals being

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* London: C. and E. Layton. 1903.

$$20A + Bc^{19\frac{1}{2}} \cdot \frac{c^{20}-1}{c-1},$$

$$20A + Bc^{39\frac{1}{2}} \cdot \frac{c^{20}-1}{c-1},$$

and
$$20A + Bc^{59\frac{1}{2}} \cdot \frac{c^{20}-1}{c-1}.$$

Differencing these, we have an obvious means of deducing the value of $\log c^{20}$, and hence the values of the other constants.

The following are the constants resulting from this grouping†:—

$A = {\cdot}747127$. $B = {\cdot}00680912$. $\log_{10} c = {\cdot}0462118$.

The values of A and B are here given in weeks, and would have to be divided by $52\frac{1}{6}$ to furnish the corresponding yearly values.

At the outset, in considering to what extent of the table a Makeham curve could be fitted, one or two points presented themselves which made it clear that the hypothesis would not apply for the whole of life. At the beginning of the table the evidence points in my view to a fall for a few years in the rate of sickness, a feature which is not singular to this section of the Society's experience but is reflected in the observations relating to other occupation groups. Again towards the later years of life, i.e., from about age 75, there is an unmistakable decline in the ratio at which the rate of sickness increases and a tendency towards a constant rate of sickness of about 40 weeks per annum as will be seen from the following average unadjusted rates:—

Age group	Average rate of sickness in weeks
68—72	13·78
73—77	21·24
78—82	29·02
83—87	34·72
88—92	37·25
93—97	39·73

Considerable weight may I think be attached to these quinquennial rates since they are based upon a relatively large number of observations, one of the distinctive features of the new Manchester Unity Experience being the extent of the data at the old ages.

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* In speaking here, and in what follows, of a Makeham curve or graduation I refer to the hypothesis formulated at the beginning of this paper and not to Makeham's own theory of sickness.

† [Mr W. Palin Elderton has at my suggestion worked out $\log_{10} c$ by the method indicated by him in *Biometrika*, Vol. II. p. 503. To fit Mr Spencer's range from 19 to 78, he took the origin of his exposed to risk normal curve at 42·5 years, and he found $\log_{10} c = {\cdot}046,0043$. Considering the complete difference of method, Mr Elderton's result closely confirms Mr Spencer's value. K. P.]

It is of course clear that neither the decline in the rate of sickness from age 16 to about age 20 nor the bend in the curve exhibited at the other end of the table could be reproduced by a Makeham graduation without the aid of supplementary curves, and as for the moment I was concerned not so much with a graduation of the whole table as with an attempt to fit an $A+Bc^x$ curve to as great an extent of the table as possible I decided to confine my attention to the facts for ages 19—80. I made various groupings all of which gave a value of $\log_{10} c$ approximating to ·046. Eventually however I chose the data for ages 19—78 for closer investigation and from these deduced the constants given above.

The following table shows rates of sickness based on these constants. For purposes of comparison the ungraduated rates are also given, together with the adjusted rates published in Mr Watson's volume. These latter it may be remarked were obtained from the rough rates by the application of a 15 term summation formula.

Central Rates of Sickness.

Age	Rates on Makeham Hypothesis	Ungraduated Rates	Official Adjusted Rates	Age	Rates on Makeham Hypothesis	Ungraduated Rates	Official Adjusted Rates
20	·807	·823	·815	*50*	2·215	2·146	2·177
21	·814	·808	·810	*51*	2·380	2·358	2·347
22	·822	·810	·814	*52*	2·564	2·550	2·539
23	·830	·824	·823	*53*	2·767	2·764	2·750
24	·839	·837	·834	*54*	2·994	2·958	2·978
25	·850	·853	·845	*55*	3·247	3·240	3·221
26	·861	·851	·856	*56*	3·527	3·496	3·481
27	·874	·881	·867	*57*	3·839	3·773	3·759
28	·888	·876	·881	*58*	4·186	4·096	4·065
29	·904	·890	·898	*59*	4·573	4·398	4·413
30	·922	·917	·918	*60*	5·002	4·799	4·821
31	·942	·952	·941	*61*	5·480	5·320	5·310
32	·963	·959	·966	*62*	6·013	5·827	5·893
33	·988	1·000	·991	*63*	6·602	6·523	6·570
34	1·015	1·009	1·020	*64*	7·260	7·394	7·335
35	1·045	1·063	1·052	*65*	7·991	8·190	8·183
36	1·078	1·086	1·091	*66*	8·804	9·290	9·117
37	1·115	1·127	1·136	*67*	9·709	10·035	10·153
38	1·157	1·176	1·190	*68*	10·715	11·136	11·302
39	1·203	1·257	1·249	*69*	11·834	12·472	12·559
40	1·254	1·315	1·313	*70*	13·079	14·092	13·913
41	1·311	1·392	1·378	*71*	14·463	15·384	15·346
42	1·374	1·437	1·443	*72*	16·003	16·952	16·846
43	1·444	1·510	1·508	*73*	17·716	18·202	18·409
44	1·522	1·582	1·574	*74*	19·621	19·951	20·036
45	1·610	1·632	1·643	*75*	21·740	21·619	21·713
46	1·706	1·726	1·717	*76*	24·098	23·641	23·397
47	1·814	1·813	1·804	*77*	26·719	25·055	25·061
48	1·934	1·877	1·907	*78*	29·635	26·776	26·688
49	2·067	2·037	2·030	*79*	32·878	28·050	28·265

It will be seen that on the whole my graduated rates run very closely to the unadjusted values until about age 55. Above that age the agreement is not invariably so marked and from age 75, as might have been anticipated, the two series diverge rapidly. Obviously the graduation fails to fit the raw data above age 80 and, apart from this circumstance, the fact that after a certain point the value of the force of sickness would exceed unity, or $52\frac{1}{6}$ weeks per annum, forms a theoretical objection to the hypothesis as applied to the final ages in the table. Makeham's own theory of sickness avoids the latter difficulty, though, after investigation, I conclude that it fails satisfactorily to represent the sickness after age 80 in the table under examination.

To show the extent to which the graduated rates of sickness reproduce the actual sickness experienced when multiplied at each age by the number "Exposed to Risk" I now give the following comparison:—

Age Group	Expected weeks of Sickness	Actual weeks of Sickness	Excess of Expected over Actual	Ratio per cent. of Excess to Actual
16—29	659,739	658,029	+ 1,710	+ ·3
30—39	645,877	652,620	− 6,743	−1·0
40—49	700,681	715,141	−14,460	−2·0
50—59	938,759	924,705	+14,054	+1·5
60—69	1,035,598	1,046,278	−10,680	−1·0
70—79	1,009,216	1,005,771	+ 3,445	+ ·3
Totals	4,989,870	5,002,544	−12,674	− ·25

As a final test of the graduation I append the values at 3°/₀ interest of a benefit of £1 per week during sickness throughout life as compared with those published officially, the mortality assumed in each case being that exhibited by the members of the Society in Non-Manufacturing Districts, designated Area 1 in Mr Watson's volume. For the purpose of calculating the former values it was necessary to deal with the sickness above age 79 and I made the convenient assumption of a constant rate of sickness from age 80 onwards of 34·634 weeks per annum, this being the value of $A + Bc^{80}$ given by my constants. The average rate of sickness at these ages according to the observations is only 32·724 weeks per annum, but the adoption of the higher value not only avoids the assumption of a diminishing rate of sickness but introduces a factor which compensates for the deficiency of Expected Sickness up to age 79. Strictly speaking perhaps I should have worked out monetary values from the unadjusted data for comparison with those now calculated, but since the graduation upon which the official values are based is in effect a smoothing-down process which reproduces the prominent characteristics of the rough data, the published values may confidently be employed as a standard of comparison.

Values at 3 per cent. of a Benefit of £1 per week during Sickness throughout life.

Age	On Makeham Hypothesis	As published
	£	£
20	57·44	57·39
25	63·26	63·22
30	70·25	70·24
35	78·35	78·32
40	87·74	87·58
45	98·54	98·01
50	110·50	109·88
55	123·84	123·21
60	137·67	137·34

PRELIMINARY NOTE ON THE PROTECTIVE VALUE OF COLOUR IN MANTIS RELIGIOSA.

By A. P. di CESNOLA, Queen's College, Oxford.

During last summer vacation, at Professor Weldon's suggestion, I undertook a small series of experiments upon protective coloration from a statistical standpoint. The form chosen was *Mantis religiosa*, which occurs in Italy (where the experiments were made) in two forms, a green and a brown. It is interesting to notice that the green form is always found upon green grass, the brown form upon grass burnt by the sun. The green form is characterised by its more sluggish behaviour; the brown form is more active.

For the purpose of this experiment I collected 110 specimens of *Mantis religiosa*, 45 green and 65 brown. Each individual was tied by a silk thread about six inches long to a plant, the thread being tied round the animal's thorax, and each *Mantis* being attached to a separate plant.

The individuals were divided into four groups, two green and two brown; of the green individuals, 20 were tied to green plants in a place covered with green herbage, the remaining 25 being tied to brown plants in a place where the herbage generally was burnt and brown. In the same way, 20 of the brown individuals were tied to brown plants in a burnt-up spot, and 45 were tied to green plants on a green piece of ground. The whole series was tied in this way and exposed on August 15th, and observations were made daily during seventeen days.

The death-rate during the period of observation may be gathered from the diagrams Figs. 1 and 2, and it will be seen that during the whole period the 20 green individuals exposed among green grass, and the 20 brown individuals exposed among brown grass were untouched by enemies, so that all of them survived.

Of the 25 green individuals exposed upon brown grass, the last was killed by August 25th, eleven days after the commencement of the experiment. Of the 45 brown individuals, exposed upon green grass, ten were left on September 1st. On the evening of September 1st a gale occurred, which ultimately swept away the remaining individuals, and brought the experiment to a conclusion.

Of the individuals which died, nearly all were killed by birds; but of the 25 green individuals exposed on brown grass, five were killed by ants.

It will of course be necessary to repeat the experiments upon a larger scale; but they seem to show in a fairly convincing manner the value of protective coloration.

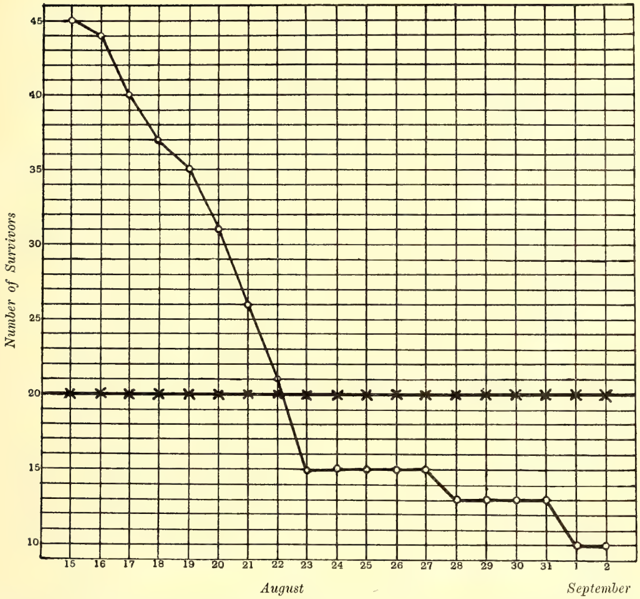

FIG. 1. Record of observations of 65 brown individuals of *Mantis religiosa*, 45 exposed on green and 20 on brown herbage. The circles show the number of individuals on the green herbage alive on each day of the experiment, the crosses the number of individuals alive on brown herbage.

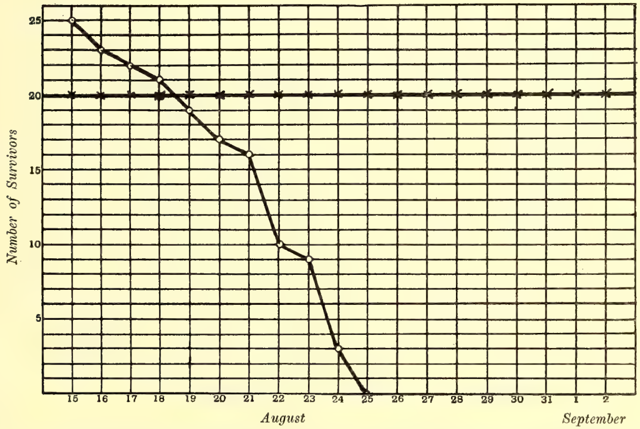

FIG. 2. Record of 45 green individuals of *Mantis religiosa*, 25 exposed on brown herbage, and 20 on green. The circles show the number of those on brown herbage surviving on each day of the experiment, the crosses show the number of survivors on green herbage.

MEASUREMENTS OF ONE HUNDRED AND THIRTY CRIMINALS.

By G. B. GRIFFITHS, M.R.C.S., L.R.C.P., Dy. Medical Officer,
H.M. Prison Service.

WITH INTRODUCTORY NOTE

By H. B. DONKIN, M.D., F.R.C.P., One of H.M. Prison Commissioners and
Directors of Convict Prisons.

These Tables are intended only as an indication of the method of certain anthropometrical observations which are now being carried out by the good-will of the Medical Officers of the English Convict Prisons. No conclusion from such a small number of cases is, of course, to be attempted. The whole scheme, of which these notes are but a sample instalment, has for its object the collection of large numbers of observations, anthropometrical and otherwise, on criminals undergoing sentences of three years and upwards, without any selection whatever. It is hoped that in the course of time such results will be attained, as may possibly throw some light on criminological questions which have been raised, and sometimes prematurely solved, by various writers.

The present preliminary observations were made by Dr Griffiths at Parkhurst Prison according to forms decided on in consultation with Dr Smalley, the Medical Inspector of Prisons, and myself. It is to be noted that they differ from those which will be made in future in that a certain selection of cases has been made, the larger scheme not having been completely formulated at the time.

H. B. DONKIN.

Method of Measurement.

The person to be measured is seated and looking directly to his front, the head being in the "Horizontal Position," i.e. so that a pen placed clerkwise over the ear will join the external angle of the eye and the topmost junction of the external ear and head.

Next, a steel tape, weighted at either end, is placed on the head at the External Occipital Protuberance and carried forward along the Vertex and middle of the forehead to the chin. The weight will keep this tape in position and a similar weighted tape is placed coronally from one External Auditory Meatus to the other over the Vertex. Where these steel tapes cut each other on the Vertex it is agreed for the purposes of these investigations to call the Bregma.

The Antero-posterior Curve is the first measurement taken by means of a steel measuring tape joining the Nasion and External Occipital Protuberance. This curve will be cut into an Anterior and a Posterior segment by the tape stretching from one External Auditory Meatus to the other.

Next, with the crossed tapes still in position, the Horizontal Curve is taken by passing the measuring tape round the head from the Ophryon along the right side, over the External Occipital Protuberance and forward along the left side to the Ophryon again. The crossed tapes will cut this Circumference into four moieties:

(i) Right Anterior.
(ii) Right Posterior.
(iii) Left Posterior.
(iv) Left Anterior.

In taking this measurement, (1) the whole Circumference is noted, then (2) the distance from the Ophryon to the Right Auricular line, i.e. the tape joining the External Meatus; next, the number on the tape at the External Occipital Protuberance where it cuts the Anterior Posterior one; next, the number on the Left Auricular line.

Supposing (1) to be 15 cm., that is the measurement of the Right Anterior Segment, and (2) that the tape marks 30 cm. over the External Occipital Protuberance, $30 - 15 = 15$, which is the measurement of the Right Posterior Segment. The two remaining segments are similarly got by subtraction.

The Cranial Height is taken:—a vertical standard with a horizontal arm at right angles which will slide up and down is placed by the subject's side with the horizontal arm pointing coronally across the head and just touching the Bregma. One limb of the callipers is placed in the middle of the External Auditory Meatus, and the other so as just to touch the lower surface of the horizontal arm. The vertical distance is the Vertical Height.

Cranial Length is the direct distance from the Glabella to the External Occipital Protuberance.

Cranial Breadth is the greatest Bi-parietal Diameter.

The Face Length is taken as the distance from just below the middle point of the chin to the Nasion.

The Face Breadth is the greatest Bi-Zygomatic Diameter.

"Facial Symmetry" is not a measurement but is judged by carrying the steel tape from the External Occipital Protuberance forward to the middle point of the Chin and noticing which side is greater.

"Nasal Deflection" is judged in a similar manner.

The Curve of the Forehead is taken:—the limbs of the callipers are fixed at 10 cm. apart, and one limb placed on the Nasion and the other on the Vertex in the middle line. The curve between these two points is measured with the tape and is the Forehead Curve.

The Auricular-Alveolar, Auricular-Nasal, Auricular-Occipital, and Auricular-Mental Diameters are taken with the callipers, and are the distances between the Middle of the External Auditory Meatus and the Alveolar Point, the Nasion, the External Occipital Protuberance, and the Chin respectively.

The Chin and Occipital Projections are taken by placing the standard behind the subject with the horizontal arm pointing forward. A weighted tape is hung from the horizontal arm and hangs plumb, just touching the External Occipital Protuberance or Chin; and the distance taken by callipers between the External Auditory Meatus and a steel bar at right angles to this plumb-line is the Projection required.

The head measurements are all expressed in millimetres.

The Horizontal Circumference is divided into four segments to facilitate the comparison of the Anterior and Posterior and Right and Left Segments.

The following terms and abbreviations are used in describing the shape of the Nose:—

Rect. = Rectilinear, Concave, Convex, Hump, Und. = Undulating, refer to shape from Nasion to tip; Hor. = Horizontal, Elev. = Elevated, Desc. = Descending, refer to angle from tip to junction with upper lip.

The present investigations have been made on 100 "Ordinary" and 30 Lunatic Criminals.

Cephalic Index	Vertical Index	Length
·2	60·7	123
·6	72·9	120
·8	70·5	129
·5	72·6	129
·3	70·4	125
·2	64·1	138
·9	72·6	129
·2	70·1	121
·7	70·3	118
·8	60·2	120
·2	58·7	134
·2	69·1	134
·4	63·1	127
·0	65·8	130
·4	67·6	132
·0	59·5	120
·9	71·8	130
·8	62·0	126
·1	72·2	114
·4	71·6	124
·9	63·5	110
·2	74·1	124
·3	65·2	117
·0	64·1	112
·6	69·0	136
·0	68·5	130
·6	66·6	127
·9	70·2	120
·2	72·5	140
·7	68·8	130
·0	65·3	120
·9	66·3	123
·6	72·9	135
·6	72·4	132
·5	69·8	127
·7	69·1	146
·1	64·7	135
·5	67·3	125
·8	67·9	127
·0	69·0	127
·0	72·3	132
·0	66·6	120
·0	76·4	121
·0	64·2	137
·8	67·0	112
·0	69·5	118
2	62·9	117
7	70·7	117
5	72·9	122
7	67·5	135
4	80·9	134
·6	70·8	123
1	79·6	132
7	73·5	112
5	75·8	114
3	73·3	125
3	69·8	127
7	69·4	121
4	77·0	129
8	69·4	128
5	76·5	126
3	71·5	122
6	72·5	123
5	70·0	129
0	77·3	117
8	66·5	139
1	69·2	126
7	72·5	130
5	72·0	114
0	61·9	120
0	64·0	126
5	69·8	120

100 "ORDINARY" CRIMINALS.

TABLE I.

Reg. and Crime	Cranium															Face					Forehead		Nose									Ears			General Observations
	Antero-posterior Curve	Ant. Segment	Post. Seg.	Horizontal Circum.	Right Ant.	R. Post.	L. Post.	L. Ant.	Ant. Seg.	Post. Seg.	Cranial Height	Cranial Length	Cranial Breadth	Cephalic Index	Vertical Index	Length	Breadth	Facial Index	Symmetry	Eye-brows. C = concurrent N = not concurrent	Curve	High (H), Low (L), Receding (R), Med. (M), Broad (B)	General Shape	Deflection	Auriculo-Alveol. Diameter	Auriculo-Nasal Diameter	Gnathic Index	Auriculo-Occip. Diameter	Occipital Projection	Auriculo-Mental Diameter	Chin Projection	Length—Right	Length—Left	Lobule. A = adherent N = not adherent	
ZH 127 Wounding with intent to murder	315	180	135	558	145	140	140	133	278	280	121	198	145	73·2	60·7	123	133	108·1	=	C	110	HB	Concave, Elev.	L	122	120	101·6	133	100	145	101	70	68	N	
N 532 ,,	300	160	140	545	130	150	135	130	260	285	140	192	153	79·6	72·9	120	138	115·0	=	C	112	LR	Concave, Elev.	L	109	110	99·0	134	107	134	90	70	68	A	
WGN 964 ,,	310	165	145	560	145	145	145	125	270	290	139	197	155	77·8	70·5	129	133	103·1	L+	C	110	MR	Rect., Hor.	L	115	116	99·0	148	108	130	85	69	69	N	
L 623 ,,	300	155	145	563	130	150	160	123	253	310	138	190	155	81·5	72·6	129	136	105·4	L+	C	110	HB	Hump, Hor.	L	110	114	96·4	140	118	133	91	59	60	N	
U 327 ,,	315	160	155	565	120	155	145	145	265	300	136	193	155	80·3	70·4	125	143	114·4	=	C	105	MB	Concave, Hor.	Nil	110	116	94·8	133	119	134	96	52	62	N	
U 88 ,,	305	150	155	550	140	150	130	130	270	280	127	198	145	73·2	64·1	138	138	100·0	L+	C	115	MR	Convex, Elev.	L	118	124	95·1	135	125	143	106	65	66	A	
V 356 ,,	300	160	140	555	130	140	150	135	265	290	138	190	150	78·9	72·6	129	141	109·3	L+	N	110	MB	Rect., Elev.	R	114	112	101·7	140	117	130	91	61	61	N	
KP 260 ,,	350	170	180	548	140	100	175	133	273	275	130	194	146	75·2	70·1	121	132	109·0	=	C	110	MBR	Und., Elev.	R	117	115	101·7	141	102	130	91	66	65	A	Locomotor Ataxy
X 53 ,,	315	160	155	555	130	140	155	130	260	295	135	192	155	80·7	70·3	118	139	117·7	L+	C	108	HB	Concave, Elev.	R	118	120	98·3	128	93	132	88	58	58	N	W. M.
V 357 ,,	305	160	145	540	130	130	150	130	260	280	112	185	143	77·3	60·2	120	135	112·5	L+	C	112	HB	Hump, Hor.	R	119	116	102·5	124	113	131	103	55	56	A	W. M.
W 433 ,,	305	165	140	550	140	145	135	130	270	280	114	194	144	74·2	58·7	134	136	101·4	=	N	105	MB	Und., Hor.	R	117	118	99·1	134	110	133	90	68	68	N	
X 176 ,,	308	180	128	560	130	140	140	150	280	280	137	198	155	78·2	69·1	134	137	102·7	=	C	104	MB	Rect., Hor.	Nil	115	120	95·8	140	127	135	95	63	64	A	
Y 428 ,,	305	165	140	545	130	140	135	140	270	275	118	187	156	83·4	63·1	127	143	112·5	=	C	110	HB	Und., Hor.	R	117	119	98·3	117	108	137	104	70	72	N	[tuberance
Z 134 ,,	325	165	160	590	140	150	160	140	280	310	135	205	160	78·0	65·8	130	135	103·8	=	C	110	HSq.	Concave, Elev.	R	115	116	99·1	139	106	132	98	63	70	A	Depression above ext. occip. pro-
Z 426 ,,	308	160	148	565	135	135	150	145	280	285	132	195	155	79·4	67·6	132	142	107·5	L+	C	103	HB	Rect., Hor.	R	112	116	96·5	140	104	123	96	65	66	A	
Z 225 ,,	315	180	135	585	145	145	150	145	290	295	119	200	160	80·0	59·5	120	142	118·3	L+	C	115	HB	Und., Elev.	L	115	117	98·2	127	100	139	97	62	64	N	Depression above ext. occip. pro-
a 74 ,,	320	180	140	580	135	160	140	145	280	300	143	190	161	80·9	71·8	130	140	107·7	=	C	104	HB	Und., Rect.	Nil	121	120	100·8	134	98	134	93	61	66	N	[tuberance. German
a 45 ,,	300	160	140	560	125	165	135	135	260	300	121	195	150	76·8	62·0	126	133	105·5	=	C	115	MB	Rect., Elev.	L	110	113	97·3	124	112	130	89	53	56	N	
a 137 ,,	280	170	110	535	135	145	130	125	260	275	130	180	155	86·1	72·2	114	143	125·5	=	C	105	LB	Concave, Elev.	Nil	107	110	97·2	127	114	95	128	64	66	A	
a 370 ,,	315	168	147	545	140	145	135	125	265	280	135	194	153	78·4	71·6	124	137	110·4	L+	C	104	LB	Rect., Hor.	R	115	113	101·7	142	85	127	88	62	62	A	
a 420 ,,	300	150	150	550	140	140	140	130	270	280	124	195	150	76·9	63·5	110	135	122·7	L+	N	110	MB	Und., Desc.	R	113	113	100·0	133	99	135	100	63	68	A	
b 120 ,,	292	165	127	530	130	135	130	135	265	265	129	174	157	90·2	74·1	124	145	117·9	=	C	112	HB	Convex, Desc.	R	110	112	98·3	126	94	136	94	60	58	A	
b 467 ,,	320	160	160	545	140	130	135	140	280	265	124	190	147	77·3	65·2	117	155	115·3	L+	C	110	MB	Und., Elev.	R	114	110	103·6	127	107	129	100	57	59	A	
b 326 ,,	300	155	145	540	140	130	130	140	280	260	120	187	146	78·0	64·1	112	133	118·7	L+	C	115	MB	Rect., Hor.	R	113	114	99·1	120	117	120	106	49	55	A	
b 343 ,,	350	190	160	580	160	135	145	140	300	280	136	197	149	75·6	69·0	136	130	95·5	R+	C	105	MB	Concave, Elev.	R	118	119	99·1	130	96	135	105	59	62	A	
IX 472 ,,	350	180	150	575	150	135	145	145	295	280	137	200	160	80·0	68·5	130	146	112·3	L+	C	105	MB	Concave, Hor.	L	119	123	96·7	135	96	135	113	63	63	N	
b 252 Forgery	340	165	175	595	135	160	170	130	265	330	140	210	163	77·6	66·6	127	136	107·0	R+	C	105	HB	Hump, Desc.	R	109	110	94·3	145	91	135	104	63	63	N	
b 371 Embezzlement	294	160	134	555	125	145	140	145	270	285	137	195	150	76·9	70·2	120	138	115·0	=	C	110	MB	Rect., Elev.	R	108	120	90·0	130	102	120	92	56	57	A	Rudiment of Darwin's Tubercle
a 433 Falsifying Accts	315	155	160	570	140	145	145	140	280	290	143	197	160	81·2	72·5	140	148	105·7	L+	N	110	HB		R	117	122	95·9	138	107	138	107	62	62	N	
b 372 Forgery	315	160	155	560	140	140	150	130	270	290	133	193	150	77·7	68·8	130	135	103·8	=	C	110	MB	Concave, Hor.	R	115	115	100·0	127	112	118	98	59	58	A	Rudiment of Darwin's Tubercle
X 69 Theft	340	180	160	580	150	150	140	140	290	290	128	196	153	78·0	65·3	120	143	119·1	=	C	110	MB	Hump, Rect.	L	116	118	98·3	118	128	140	109	62	58	A	Darwin's Tubercle
b 265 ,,	305	160	145	570	140	140	150	140	280	290	128	193	160	82·9	66·3	123	139	113·0	L+	N	110	MB	Concave, Elev.	R	113	114	99·1	132	113	126	80	50	57	A	
b 378 Felony ..	320	170	150	545	135	145	130	135	270	275	135	185	140	75·6	72·9	135	136	100·7	L+	C	105	LB	Hump, Rect.	R	121	119	101·6	120	115	135	105	63	63	A	
b 301 Fraud	330	165	165	580	130	160	150	140	270	310	142	196	160	81·6	72·4	132	147	111·3	=	C	110	MB	Hump, Rect.	Nil	117	120	97·5	130	104	140	113	61	62	N	
a 339 Theft	300	165	135	545	140	130	150	125	265	280	130	186	148	79·5	69·8	127	130	102·3	L+	C	110	MB	Concave, Elev	R	110	110	100·0	126	105	120	94	55	59	A	
L 466 ,,	320	155	165	555	130	140	155	130	260	295	130	188	150	79·7	69·1	140	143	97·9	=	N	105	MB	Hump, Rect.	Nil	120	118	101·7	125	112	132	105	63	63	A	
a 141 Receiving	350	195	155	610	160	145	185	120	280	330	130	210	162	77·1	64·7	135	150	111·1	L+	C	115	HB	Concave, Elev.	R	124	124	100·0	134	113	140	95	65	70	A	
Na 48 Theft	310	165	145	545	130	135	150	130	260	285	128	190	155	80·5	67·3	125	135	108·0	L+	N	110	MB	Concave, Elev.	R	113	115	98·2	130	85	125	102	64	64	A	
a 474 Burglary	345	190	155	570	130	150	150	140	270	300	138	203	152	74·8	67·9	127	140	110·2	L+	C	110	LR	Und., Elev.	R	120	120	100·0	130	110	135	100	65	65	N	
b 462 Theft	330	175	155	565	130	150	150	135	265	300	138	200	150	75·0	69·0	127	138	108·6	L+	C	110	LB	Concave, Rect.	R	120	115	104·3	138	123	146	110	67	67	A	
b 349 Felony	320	160	160	560	140	140	140	140	280	280	139	192	144	75·0	72·3	132	135	102·2	L+	C	115	MB	Und., Elev.	R	105	112	93·7	132	113	114	92	56	55	A	
b 361 Theft	320	160	160	560	140	150	120	150	290	270	130	195	156	80·0	66·6	120	143	119·1	=	N	105	HB	Rect., Elev.	Nil	119	120	100·2	131	108	130	114	56	56	N	
Wb 361 Theft	310	170	140	545	150	120	150	125	275	270	143	187	146	78·0	76·4	121	137	113·2	L+	C	105	MB	Rect., Hor.	R	115	116	99·1	130	108	133	104	65	67	N	
TNSb 335 Theft	310	155	155	565	145	135	155	130	275	290	124	193	156	80·6	64·2	137	137	100·0	L+	C	105	HB	Rect., Hor.	R	112	110	96·5	128	114	131	82	62	65	N	Hairs on tips of ears
b 357 Shop breaking...	320	180	140	550	140	150	110	150	290	260	130	194	149	76·8	67·0	112	134	119·6	L+	N	120	LR	Concave, Elev.	R	115	111	103·6	130	108	127	102	55	61	A	
b 321 ,, ...	310	160	150	540	125	140	155	120	245	295	130	187	151	80·0	69·5	118	137	116·1	=	C	110	LR	Rect., Hor.	L	114	112	101·7	122	122	122	89	58	58	A	
LKTb 242 Burglary ...	310	155	155	575	140	145	160	130	270	305	129	205	146	71·2	62·9	117	128	109·4	L+	C	115	MB	Und., Elev.	R	112	115	97·3	140	113	129	103	49	44	A	
DMQL 289 Theft	320	170	150	560	140	135	155	130	270	290	140	198	150	75·7	70·7	117	140	119·7	L+	C	110	MB	Und., Desc.	Nil	114	116	98·2	135	100	124	95	71	67	N	
b 320 Receiving	310	165	145	555	140	140	140	135	275	280	132	181	162	89·5	72·9	122	148	121·3	L+	C	105	MB	Concave, Elev.	Nil	121	121	100·0	127	92	123	112	56	60	N	
LISY 1261 Theft	310	155	155	575	140	140	160	135	275	300	135	200	155	77·7	67·5	135	132	97·7	L+	C	110	MB	Convex, Hor.	R	117	120	97·4	135	105	132	88	58	56	N	
P 140 Murder	320	165	155	563	140	145	145	133	273	290	157	194	156	80·4	80·9	134	136	101·4	=	C	105	MB	Concave, Hor.	R	116	119	97·4	125	98	134	97	59	59	A	
Q 91 ,,	330	158	172	565	140	130	155	140	280	285	136	192	151	78·6	70·8	123	139	113·0	L+	C	110	HB	Rect., Hor.	R	110	118	93·2	133	110	128	87	60	65	A	
Q 433 ,,	315	178	137	550	150	135	130	135	285	265	153	192	150	78·1	79·6	132	146	110·6	R+	N	110	MB	Rect., Desc.	L	118	115	102·6	124	116	136	85	58	62	A	
R 126 ,,	320	167	153	550	145	135	130	140	285	265	139	189	147	77·7	73·5	112	129	115·1	R+	C*	110	H Projecting	Rect., Hor.	L	115	116	99·1	116	113	134	103	59	59	A	[of External Ears
R 388 ,,	305	158	147	530	130	120	150	130	260	270	142	187	145	77·5	75·8	114	133	116·6	R+	C	110	LB	Rect., Elev.	R	112	120	93·2	125	113	125	97	56	48		Meati imperforate : Mere vestiges
T 397 ,,	320	175	145	555	145	135	140	135	280	275	143	195	147	75·3	73·3	125	132	105·6	=	C	112	MB	Rect., Elev.	R	116	113	102·6	133	107	134	88	59	65	A	
R 475 ,,	325	177	148	570	150	145	140	135	285	285	139	199	150	75·3	69·8	127	127	100·0	R+	C	105	HB	Concave, Elev.	Nil	112	114	98·2	133	115	143	104	62	62	N	Darwin's Tubercle L.
T 403 ,,	310	175	135	560	155	140	145	120	275	285	134	193	154	79·7	69·4	121	137	113·2	R+	C	110	MB	Rect., Elev.	L	122	120	101·6	121	111	137	104	63	62	N	
M 547 ,,	320	180	140	560	140	135	145	140	280	280	138	195	155	79·4	77·0	129	141	109·2	=	C	105	HB	Rect., Hor.	R	122	120	101·6	124	88	142	125	68	72	A	
H 826 ,,	295	145	150	545	128	146	141	130	258	287	132	190	140	76·8	69·4	128	131	102·3	=	C	105	HN	Convex, Elev.	R	121	113	107·0	120	95	130	106	63	66	A	Depression in sup. occip. region
T 729 ,,	350	155	195	573	130	160	155	126	258	315	153	200	149	74·5	76·5	120	143	113·4	R+	C	110	MB	Convex, Hor.	R	122	125	97·6	125	92	145	127	66	63	A	
M 145 ,,	320	155	165	558	145	135	146	132	277	281	138	193	155	80·3	71·5	122	126	103·2	=	N	104	HB	Rect., Hor.	R	113	113	100·0	121	82	140	111	56	50	A	
M 744 ,,	315	155	160	543	138	142	135	128	266	277	140	193	147	75·6	72·5	123	123	100·0	=	N	102	HB	Convex, Hor.	R	121	115	105·2	120	104	133	108	62	64	N	
N 399 ,,	320	165	160	565	145	150	145	125	270	295	140	200	153	76·5	70·0	120	121	93·7	=	N	110	HB	Rect., Hor.	R	123	122	100·8	118	101	145	93	66	68	A	
N 63 ,,	305	155	150	565	140	155	145	125	265	300	147	190	154	81·0	77·3	117	127	108·5	=	C	110	B	Hump, Hor.	R	121	120	100·8	120	104	130	96	65	66	A	
Q 430 ,,	310	158	152	565	130	150	143	142	272	293	135	203	156	76·8	66·5	139	136	97·8	R+	C	110	LB	Hump, Elev.	R	128	125	102·4	140	122	148	98	61	66	A	
U 548 ,,	345	185	160	583	150	150	145	138	288	295	142	205	152	74·1	69·2	126	142	112·6	R+	C	110	HB	Convex, Elev.	Nil	115	116	99·1	137	125	140	97	60	64	N	Malars prominent
V 207 ,,	320	165	155	550	145	135	148	124	269	283	138	190	144	75·7	72·5	130	133	102·3	=	C	115	LB	Rect., Elev.	R	115	117	98·3	127	115	135	93	60	57	N	
W 144 ,,	310	155	155	548	130	145	150	123	253	295	139	193	146	75·6	72·0	114	130	114·0	L+	C	115	M	Concave, Elev.	R	110	105	104·7	137	114	122	95	58	60	N	
V 384 ,,	345	172	173	550	145	135	135	135	280	270	122	197	138	70·0	61·9	120	123	102·5	=	C*	108	MB	Hump, Elev.	R	117	116	100·8	115	102	132	103	58	59	A	
W 313 ,,	315	145	170	550	140	140	145	125	265	285	119	185	150	81·0	64·0	126	122	96·8	=	C	117	HB	Rect., Hor.	L	107	109	98·3	119	115	130	94	53	53	A	
W 504 ,,	335	155	180	540	140	140	145	121	261	285	130	186	150	80·6	69·8	120	133	110·8	=	C	110	MB	Convex, Elev.	R	110	115	95·6	110	103	135	90	57	61	N	

* Concurrence slight.

Cephalic Index	Vertical Index
79·8	69·5
78·7	73·0
72·8	64·0
71·7	67·3
77·0	67·8
75·6	71·2
78·1	70·8
95·7	69·6
76·3	72·6
76·3	70·7
82·0	68·2
78·9	63·1
77·3	64·9
75·0	70·0
81·0	71·0
73·7	60·9
76·2	63·3
76·2	64·8
76·9	69·5
73·0	68·3
84·8	68·6
81·7	71·5
80·5	63·1
78·9	76·9
79·6	71·4
77·8	69·4
74·2	73·6
78·9	70·7

75·7	66·9
74·8	64·0
73·1	71·1
83·7	64·8
75·7	67·8
81·0	61·6
80·2	67·6
76·0	67·6
82·0	66·8
74·2	70·4
76·1	75·6
72·8	62·5
80·0	70·5
5·4	73·0
3·3	70·2
6·1	69·4
4·2	68·4
1·0	65·4
1·8	63·1
6·2	72·7
8·9	68·6
7·1	73·1
3·3	67·7
3·5	69·9
9·8	66·4
4·0	66·5
5·0	66·3
8·4	61·0
4·7	72·1
0·0	70·0

100 “ORDINARY” CRIMINALS.

TABLE I.—*continued.*

Reg. and Crime	Cranium															Face					Forehead		Nose									Ears			General Observations
	Antero-posterior Curve	Ant. Segment	Post. Seg.	Horizontal Circum.	Right Ant.	R. Post.	L. Post	L. Ant.	Ant. Sag.	Post. Sag.	Cranial Height	Cranial Length	Cranial Breadth	Cephalic Index	Vertical Index	Length	Breadth	Facial Index	Symmetry	Eye-brows, *C* = concurrent *N* = not concurrent	Curve	High (*H*), Low (*L*), Receding (*R*), Med. (*M*), Broad (*B*)	General Shape	Deflection	Auriculo-Alveol. Diameter	Auriculo-Nasal Diameter	Gnathic Index	Auriculo-Occip. Diameter	Occipital Projection	Auriculo-Mental Diameter	Chin Projection	Length Right	Length—Left	Lobule. *A* = adherent *N* = not adherent	
W 503 Murder	310	145	165	565	130	140	150	145	275	290	135	194	153	78·8	69·5	120	128	106·6	*R*	*C**	114	*LB*	Und., Elev.	*R*	120	117	102·5	133	92	132	105	60	63	*N*	Deficient of last phalanx of fingers of R. hand, R. thumb normal. Index, mid and ring fingers of L. hand are rudimentary and fastened together as in a bag. Little finger and thumb normal
X 228 ,,	335	170	165	563	150	130	140	143	293	270	141	193	152	78·7	73·0	126	139	110·3		*C*	110	*LB*	Concave, Elev.	*R*	113	122	92·6	127	117	127	86	59	60	*N*	
X 484 ,,	335	170	165	565	135	155	140	135	270	295	132	206	150	72·8	64·0	129	134	103·8		*C*	100	*LR*	Rect., Elev.	*R*	127	122	104·0	132	110	146	122	65	64	*N*	
Y 43 ,,	334	180	154	570	130	150	150	140	270	300	136	202	145	71·7	67·3	120	129	107·5	*R* +	*C*	110	*MB*	Rect., Elev.	*R*	122	118	103·3	135	112	142	122	59	60	*A*	
TX 930 ,,	320	164	150	560	140	145	135	140	280	250	132	196	151	77·0	67·8	102	135	132·3	*R*	*C*	105	*HB*	Rect., Hor.	*R*	113	120	94·1	117	105	133	109	64	66	*A*	Edentulous
Y 95 ,,	315	170	145	560	145	155	130	130	275	285	141	198	150	75·6	71·2	134	128	95·5		*C*	110	*MR*	Hump, Elev.	*R*	120	113	106·1	137	113	129	105	57	60	*N*	
Y 377 ,,	305	165	140	565	140	130	150	145	285	280	136	192	150	78·1	70·8	128	135	105·4		*N*	110	*HB*	Rect., Elev.	*R*	100	114	87·5	125	99	128	107	50	56	*N*	Tops of auricles turned over. Edentulous
Y 514 ,,	335	175	160	565	135	145	153	127	262	298	138	198	150	75·7	69·6	126	136	107·9	*L* +	*C*	115	*M* Low	Concave, Elev.	*R*	113	118	95·7	134	115	133	87	58	60	*A*	
Z 46 ,,	315	160	155	530	135	145	130	120	255	275	138	190	145	76·3	72·6	117	130	110·2	*L* +	*C*	110	*HN*	Concave, Elev.	*L*	110	110	100·0	125	110	123	95	53	55	*A*	
Z 270 ,,	340	180	160	550	150	135	135	130	280	270	138	195	149	76·3	70·7	126	135	107·1	--	*N*	112	*ML*	Concave, Elev.	Nil	122	108	112·9	127	120	140	87	58	62	*A*	
a 432 ,,	320	160	160	580	135	150	165	130	265	315	133	195	160	82·0	68·2	126	146	115·8		*C*	108	*HB*	Convex, Elev.	*R*	116	116	100·0	140	108	137	100	70	65	*N*	
Z 396 ,,	284	170	114	540	140	140	110	150	290	250	120	190	150	78·9	63·1	125	140	112·0	*L*	*C*	117	*HB*	Rect., Elev.	*R*	122	122	100·0	137	102	143	119	59	62	*N*	
Z 303 ,,	315	160	155	562	135	145	155	127	262	300	126	194	150	77·3	64·9	126	135	107·0		*C*	110	*MB*	Convex, Elev.	*R*	112	115	97·3	135	117	127	95	68	70	*N*	
EZ 861 ,,	345	180	165	570	150	130	160	130	280	290	140	200	150	75·0	70·0	127	132	103·8	*L* +	*C*	110	*LR*	Concave, Elev.	*R*	125	120	104·1	125	97	135	100	57	60	*A*	Prom. Malars
N 260 Manslaughter	310	157	153	560	140	145	140	135	275	285	135	190	154	81·0	71·0	122	130	110·5	*L*	*C*	110	*HB*	Rect., Hor.	*L*	106	107	99·0	135	100	134	95	53	62	*A*	Rudiment of Darwin's Tubercle
N 531 ,,	320	165	155	570	130	145	155	140	270	300	125	205	151	73·7	60·9	116	140	120·6	*L* +	*C*	110	*MB*	Convex, Hor.	*R*	108	109	99·0	135	102	134	110	58	60	*A*	
R 219 ,,	310	170	140	570	140	145	145	140	280	290	128	202	154	76·2	63·3	130	144	110·7	*L*	*C*	112	*LR*	Concave, Elev.	*L*	119	117	101·7	136	115	133	95	66	70	*N*	
V 455 ,,	310	150	160	530	120	170	110	130	250	280	126	185	140	76·2	64·8	125	135	108·4	*L* +	*C*	110	*ML*	Hump, Hor.	*R*	111	111	100·0	124	111	122	103	64	58	*A*	
b 466 Rape	300	165	135	555	140	140	135	140	280	275	135	194	150	76·9	69·5	130	140	107·6		*C*	110	*HB*	Convex, Hor.	Nil	116	122	95·0	130	104	125	118	62	62	*N*	
MV 278 Rape	320	150	170	540	130	150	135	125	255	285	132	193	141	73·0	68·3	125	130	104·0	*L* +	*C*	110	*MB*	Rect., Hor.	Nil	117	114	102·6	125	100	133	105	56	59	*A*	
U 559 ,,	310	160	150	560	140	130	155	135	275	285	127	185	157	84·8	68·6	120	138	115·0	*L* +	*C*	110	*LB*	Rect., Hor.	*R*	118	118	100·0	118	97	135	96	53	55	*A*	
TV 580 Theft	320	170	150	550	145	125	145	135	280	270	133	186	152	81·7	71·5	128	140	109·5		*C*	110	*MB*	Rect., Elev.	Nil	110	110	100·0	125	120	125	92	60	62	*A*	
b 319 ,,	315	150	165	560	130	150	150	130	260	300	120	190	153	80·5	63·1	127	143	112·5	*L* +	*C*	110	*LB*	Concave, Hor.	*R*	120	126	95·2	127	110	134	84	51	53	*A*	Outstanding Ears
b 338 Burglary	340	175	165	570	140	150	160	130	290	310	150	195	154	78·9	76·9	120	133	110·8	*L*	*C*	105	*LB*	Concave, Elev.	*R*	116	119	87·4	126	110	140	85	66	66	*A*	
Y 366 Theft	325	175	150	540	130	160	115	135	265	275	130	182	145	79·6	71·4	122	133	109·0	*L* +	*C*	110	*L*	Concave, Elev.	*R*	112	103	108·7	120	95	135	95	60	62	*A*	
V 334 Forgery	320	170	150	555	140	150	130	135	275	280	132	190	148	77·8	69·4	135	130	107·0	*L* +	*C*	105	*LR*	Rect., Hor.	*R*	115	117	98·2	129	107	135	110	60	57	*A*	
b 331 Theft	320	160	140	560	140	140	150	130	270	290	143	194	144	74·2	73·6	132	135	102·2	*L*	*N*	110	*MB*	Und., Hor.	*R*	112	115	97·3	134	115	122	85	60	65	*N*	
b 262 Fraud	335	160	175	575	140	150	125	160	300	275	138	195	154	79·0	70·7	134	140	104·4	*L*	*C*	110	*MB*	Convex, Des.	*R*	110	115	95·6	145	119	130	94	70	72	*N*	Very large lobes

* Concurrence slight.

30 LUNATIC CRIMINALS

TABLE II.

Reg. and Crime	Antero-posterior Curve	Ant. Segment	Post. Seg.	Horizontal Circum.	Right Ant.	R. Post.	L. Post	L. Ant.	Ant. Sag.	Post. Sag.	Cranial Height	Cranial Length	Cranial Breadth	Cephalic Index	Vertical Index	Face Length	Face Breadth	Facial Index	Symmetry	Eye-brows	Forehead Curve	Forehead	Nose General Shape	Deflection	Auriculo-Alveol. Diameter	Auriculo-Nasal Diameter	Gnathic Index	Auriculo-Occip. Diameter	Occipital Projection	Auriculo-Mental Diameter	Chin Projection	Ears Length Right	Length—Left	Lobule	General Observations
O 595 Manslaughter	340	170	170	580	150	145	155	130	280	300	138	206	156	75·7	66·9	147	144	97·9	*L* -	*C*	100			*R*	123	120	102·5	138	100	133	88	70	69	-	Palate Λ
W 298 ,,	340	160	180	585	140	155	165	130	270	315	130	203	152	74·8	64·0	123	145	117·8	*L* -	*C*	110			*R*	113	120	94·1	131	108	130	88	69	68	*N*	,, Low and Narrow
L 371 ,,	335	160	175	545	140	135	150	120	260	285	138	194	142	73·1	71·1	130	140	107·6	*R* +	*N*	103			*R*	110	112	98·2	123	110	113	85	65	65	*N*	,, Λ
ZO 321 Wounding	300	155	145	530	140	130	130	130	270	260	120	185	155	83·7	64·8	125	150	120·0	*L* +	*N*	110			*R*	120	120	100·0	120	100	135	103	65	60		,, Λ
b 359 ,,	325	180	145	545	140	155	165	145	285	260	129	190	144	75·7	67·8	124	137	110·3	*L* +	*C*	110			*R*	123	116	106·0	123	92	138	95	62	60		,, Low and Shallow
L 280 ,,	315	140	175	540	140	145	135	120	260	280	114	185	150	81·0	61·6	124	138	111·2	*L* +	*C*	103			*R*	115	115	100·0	123	100	126	82	59	56	---	,, ,, ,,
L 623 ,,	325	160	165	565	135	155	145	130	265	300	130	192	154	80·2	67·6	130	135	103·8	–	*C*	105			*L*	108	114	94·7	125	90	126	85	55	58	*N*	,, Λ
Z 257 ,,	330	170	160	550	140	140	145	125	265	285	130	192	146	76·0	67·6	125	138	110·4	*L* +	*C*	105			*R*	112	110	101·8	120	112	128	93	60	58	*N*	,, Low and Narrow
W 263 ,,	320	166	160	560	140	140	145	135	275	275	123	184	151	82·0	66·8	121	138	114·0	*R* +	*C*	105			*R*	106	108	97·1	117	102	124	118	58	64		,, Λ
P 320 ,,	340	170	170	595	150	155	165	125	275	320	148	210	156	74·2	70·4	125	134	107·2	*L* +	*C*	105			*L*	122	120	101·6	134	117	137	97	65	67	*A*	,, Narrow and Shallow
b 256 Rape	305	175	130	560	145	145	140	130	275	285	149	197	150	76·1	75·6	137	134	97·8	*L* +	*C*	100	--		*R*	107	104	102·8	133	127	125	97	67	62	—	,, Λ
Y 236 ,,	315	160	155	540	135	145	140	120	255	285	120	192	140	72·8	62·5	129	130	100·7	*L* +	*C*	110			*R*	110	109	100·8	120	100	126	72	60	57	*A*	,, Λ
W 423 ,,	300	165	135	530	135	140	130	125	260	270	127	180	144	80·0	70·5	116	135	116·3	*L*	*C*	110	--		*R*	107	118	90·6	130	92	126	83	53	55	*A*	,, Narrow and Shallow
a 155 Bestiality	350	180	170	575	145	145	155	130	275	300	149	204	154	75·4	73·0	108	139	128·7	–	*C*	110			*R*	108	112	96·4	124	112	128	97	66	65	*N*	,, Low and Shallow
MQL 64 Coining	320	180	140	550	140	125	145	140	280	270	137	195	143	73·3	70·2	125	138	110·4	*L* +	*C*	103			*R*	117	121	96·6	125	100	130	105	60	53		,, Λ
a 63 Arson	335	160	175	565	150	150	140	125	275	290	134	193	147	76·1	69·4	119	139	116·8	-	*N*	110	-		Nil	110	112	98·2	130	112	121	92	59	58		,, High and Narrow
P Theft	355	180	175	580	140	150	150	140	280	300	141	206	153	74·2	68·4	130	140	107·6	*L* +	*C*	100	—		*R*	124	119	104·2	134	115	148	103	58	54	—	,, Λ
DKTW 300 Theft	300	150	150	545	140	140	140	125	265	280	121	185	150	81·0	65·4	114	138	121·0	*L*	*C*	110			*R*	122	116	105·1	124	87	131	110	60	56	*A*	,, Λ
b 106 Theft	310	155	155	555	145	140	135	135	280	275	118	187	153	81·8	63·1	135	140	103·6	*L*	*C*	115			*R*	116	115	100·8	127	115	132	95	54	59	·	,, Λ
LFP 923 Theft	330	160	170	570	140	155	135	140	280	290	144	198	151	76·2	72·7	122	132	108·1		*C*	100			*R*	117	120	97·5	127	97	136	102	62	66	*A*	,, Narrow and Shallow
RL 454 ,,	335	170	165	535	130	140	140	125	255	280	127	185	140	75·9	68·6	128	133	103·8	*L* +	*C*	105			*R*	107	110	97·2	120	112	129	85	59	61	-	,, Narrow and High
X 259 Theft	340	185	155	580	150	150	140	140	290	290	142	194	169	87·1	73·1	112	153	136·6	*L* +	*C*	105			*L*	111	119	93·2	117	112	130	89	52	60	*A*	,, Low
LRWZ 268 Theft	325	160	165	550	180	95	145	130	310	240	126	186	155	83·3	67·7	115	138	120·0	*L* +	*N*	108			Nil	110	110	100·0	122	98	127	91	59	64	*A*	,, Shallow and Narrow
a 145 Theft	330	180	150	540	140	145	125	130	270	270	135	193	142	73·5	69·9	108	131	121·2	*L* +	*C*	100			*R*	110	111	99·0	120	90	120	97	57	63	*A*	,, ,, ,,
TW 168 Burglary	340	170	170	560	130	150	145	135	265	295	129	194	155	79·8	66·4	123	131	106·5	*L* +	*C*	103			*R*	116	112	103·5	124	102	133	90	55	57	--	,, Med. Height, Flat
WL 419 ,,	320	150	170	565	140	155	135	135	275	290	133	200	148	74·0	66·5	125	141	112·8	–	*C*	113			*L*	121	124	97·5	126	107	128	97	59	62		,, Λ
BKX 463 ,,	325	155	170	555	140	140	150	125	265	290	126	190	153	85·0	66·3	122	141	115·5	*L* +	*N*	110			*R*	112	115	97·3	122	107	124	92	68	62	*N*	,, Λ
Z 367 ,,	320	160	160	555	145	130	145	135	280	275	116	190	149	78·4	61·0	112	133	118·7	*R* +	*C*	105	—	—	*R*	108	114	94·7	123	111	120	85	55	57	*A*	,, Λ
b 25 ,,	330	160	170	540	140	135	150	121	201	285	140	194	145	74·7	72·1	115	132	114·7	*L* +	*C*	105	—	—	*R*	113	110	102·7	122	107	129	90	55	58	*A*	,, Shallow and Narrow
Y 467 Fraudulent Enlistment	350	180	170	590	150	140	145	155	305	285	140	200	160	80·0	70·0	128	142	110·9	*L* +	*C*	105	—	—	*R*	122	117	104·2	130	110	138	106	66	63	—	,, Λ

A FIRST STUDY OF THE WEIGHT, VARIABILITY, AND CORRELATION OF THE HUMAN VISCERA, WITH SPECIAL REFERENCE TO THE HEALTHY AND DISEASED HEART.

By M. GREENWOOD, Junior.

1. During the last few years, thanks to many improvements in our methods of analysis, several of the biometric constants of the human body have been investigated. The coefficients of correlation of almost all the separate bones have been ascertained with some accuracy, and the suspected relationship between intellectual and physical characters has been closely scrutinised. Under these circumstances it is strange that so little work has been done on the weights and correlations of the viscera. Even such a simple measurement as the weight of the heart does not appear to have been calculated from any adequate series of observations. English text-books of anatomy give this weight on the authority of Reid and Peacock or on that of Clendinning. These two sets of observations are based upon very few cases. Peacock and Reid's results are drawn from 181 males and 110 females, and Clendinning's from 90 and 71 respectively*. It will be evident, therefore, that no great importance can be attached to them, even if we leave on one side the fact that they afford no materials for the study of correlation.

Clearly, the only way to obtain data for the solution of problems concerning the absolute and relative weights of the viscera is to extract as large a series of observations as possible from the *post-mortem* department records of a large general hospital. The present memoir contains the preliminary analysis of such a series from the pathological data of the London Hospital.

It might be supposed that *post-mortem* records would contain a very large number of available cases, and that the weights of the various organs would be found recorded with considerable accuracy. As a matter of fact, however, simple measurements of this kind appear to be rather despised by *post-mortem* clerks, and the records are, from the quantitative point of view, very disappointing. Weights are frequently omitted altogether; sometimes we read "Spleen *about* 3 or 4 ozs."; at others, the ingenious writer appears to have given free play to his imagination, and we read of a man of forty-six years of age having a heart weighing *one* ounce! *

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* Clendinning's results are quoted in the English text-books, and also in Grisolle's *Traité de Pathologie Interne* (9th Ed. p. 200, Vol. II.). See also, K. Pearson: "Variation in Man and Woman" (*Chances of Death and other Studies in Evolution*, Vol. I. p. 316); Peacock and Reid: *London and Edinburgh Monthly Journal of Medical Science*, 1843–6, 1854.

It is much to be desired that, in future, more accurate methods of recording these simple observations should be adopted, so that large numbers of valuable facts may be rendered available for statistical inquiry. In my own research, after excluding the large majority of the examinations, there yet remained a considerable number of fairly trustworthy data suitable for tabulation, and this paper contains some of the results deduced therefrom, which it is hoped will not be without interest. I propose to divide my subject into four parts:

First. I shall discuss the average sizes, variabilities, and correlations of the heart, liver, spleen, and kidneys in the general population, diseased and normal, to be found within a London general hospital.

Secondly. I shall consider only cases in which the organs were found healthy on *post-mortem* examination. We shall thus to some extent be able to appreciate the influence of disease in modifying the biometric constants of the organs in question.

Thirdly. I propose to deal with the influence of age on the biometric constants for the viscera in man.

And, lastly. I shall consider the influence of certain special diseases from the same standpoint. All the data dealt with in this memoir are for males, the number of females in my collection being very much smaller. As far as I am aware, no investigation of this kind on the viscera has yet been undertaken, and mine does not profess in any respect to be more than a preliminary study. Its object is to draw attention to the need of better *post-mortem* room records, and to indicate the wide field of valuable research which they open up, not only to the biometrician but to the physician†.

2. *The General Hospital Population.*

In my first series of tables I have dealt, subject to certain limitations, with a random sample of a general hospital population. To avoid the extreme changes due to youthful growth or senile decay I have tabulated only cases between the ages of 25 and 55. Such a "random sample" is, of course, also a selection in that it consists solely of those patients who died in hospital, and upon whom a *post-mortem* examination was held. Thus it is far from being a random sample of the "general population" of the country, many classes of which are never found in the wards of a general hospital at all.

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* *L. H. Path. Reports*, 1899, No. 661.

† "Il ne faut jamais négliger de peser les organes, surtout ceux qui sont atteints de lésions pathologiques; le poids fournit souvent en effet des renseignements précieux sur le degré et sur l'importance des lésions; on n'oubliera pas cependant qu'il existe sur ce point des variations individuelles considérables....... Le poids total du sujet, la taille, l'âge, le sexe sont tout autant de conditions qui font varier le poids des organes eux-mêmes." (Bard: *Précis d'Anat. Path.* p. 736.)

Evidently the population of a general hospital will chiefly consist of, (i) persons acutely ill, (ii) those suffering from surgical injuries or diseases, (iii) sufferers from medical affections requiring special treatment. Chronic maladies of old age, such as bronchitis, indeed, any highly chronic disease, will be under-represented in comparison with the general death-rate. Similarly the number of cases of valvular heart disease and rarer disorders, such as *Diabetes Mellitus* or *Insular Sclerosis* and other nervous lesions, will be above the general average.

Now, as pneumonia and bronchitis, particularly the latter, form a considerable number of the so-called "terminal affections" responsible for a large majority of all adult deaths, a random thousand necropsies will not give us the information we require as to the quantitative relations of average viscera, *post-mortem*. The error resulting from too few cases of senile bronchitis will be lessened, if not minimised, by the fact that we have confined our attention to cases of less than 55 years of age. But even thus we have too many cases of valvular cardiac disease, and as this affection tends to produce hypertrophy of the heart, the average weight in the first three tables is probably a good deal higher than that of the ordinary population at death.

It is, of course, to be remembered that this "general hospital population" does not mean the "normal" or healthy one. The above remarks are merely intended to show that a thousand deaths in hospital will not be due to exactly the same causes as a thousand deaths taken at random outside, and that therefore when we proceed to select sub-groups, such as "Normal Hearts," "Hearts in Pneumonia," etc., the material we have to select from is not what it would have been had we been able to start with 1000 random deaths in the population at large. And so, if we find that the average weight or variability of an organ is diminished when we proceed to special classes, we must bear in mind that possibly the change might not have been so striking if we had had a more representative sample to start from.

General Hospital Population.

TABLE I. *Hearts with Livers.* Number 1382.

Mean Heart 13·53 ozs.	Standard Deviation 4·680 ozs.
Mean Liver 63·01 ozs.	Standard Deviation 13·314 ozs.

Correlation of Heart and Liver ·1931 ± ·0175.

TABLE II. *Hearts with Spleens.* Number 1303.

Mean Heart 13·07 ozs.	Standard Deviation 4·067 ozs.
Mean Spleen 6·61 ozs.	Standard Deviation 3·345 ozs.

Correlation of Heart and Spleen ·1827 ± ·0181.

TABLE III. *Hearts with Kidneys.* Number 1293.
Mean Heart 13·14 ozs. Standard Deviation 4·134 ozs.
Mean Kidneys 12·68 ozs. Standard Deviation 3·125 ozs.
Correlation of Heart with Kidneys ·2577 ± ·0175.

In this table the weight is that of the two kidneys taken together. To these results I add a table of the coefficients of variation*, so as to obtain some appreciation of the relative variability of the organs in question.

TABLE A.

Relative Variability in Weights.

Organ	Coefficient of Variation
Hearts with Livers ...	34·59 } mean 32·39
Hearts with Spleens ...	31·12 }
Hearts with Kidneys ...	31·47 }
Livers	... ... 21·12
Spleens	... ... 50·58
Kidneys	... ... 24·63

The substantial difference between the weights of the heart in the cases when livers were measured with hearts and the cases when either spleens or kidneys were measured is due to the fact that the 1382 cases of the former only in part cover the 1292 to 1303 cases of the latter, the additional cases, amounting to three or four hundred, are due to entries in which only two or three weights were given. It seemed desirable to include all possible cases in order to utilise as much material as possible. But there has clearly been some special reason for measuring livers in the case of very large hearts which has not arisen in the case of spleens or kidneys. Thus with livers we have hearts up to 36 ozs., but with either spleens or kidneys only up to 28 ozs.

On the whole with respect to both mean and variability, we may consider the hearts with spleens or kidneys to give a more reasonable approach to the biometric constants of the general hospital population than arises in the case of hearts with livers, where there is evidence of much more selection.

We notice at once:

(*a*) That the spleen is relatively much more variable than the heart, and the heart than the liver or kidneys.

(*b*) That the heart mean is considerably higher than that usually given in anatomical text-books†.

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[*] The coefficient of variation = 100 × Standard Deviation ÷ Mean.

[†] Peacock and Reid's result on 181 male hearts is a mean of 10·699 ozs. The coefficient of variation calculated from their figures by Pearson is 19·825. For the liver, the mean (from 84 cases) is 53·48 and the coefficient of variation 14·32 (Pearson: *op. cit.* Vol. I. p. 316). It might, however, be better to compare these numbers with the results given later for the "healthy organs." Pearson says that we may probably conclude from Peacock's own statements that he "has cut off a considerable tail of really healthy hearts weighing over 12 ozs." (*op. cit.* p. 317).

(*c*) That there are quite sensible correlations between the weight of the heart and that of the other organs.

3. *The "Normal" Heart.*

Let us now consider the "normal" heart. Evidently the ideal normal heart is hardly at present capable of measurement with respect to any character other than those related to its manner of performing its functions. Such an organ ought really to be measured during the life of its owner, and we cannot do this, as we are unacquainted with the exact relation subsisting between body weight and heart weight in the living subject. The following is, perhaps, the best approximation to the truth that we are in a position to make. Correlation tables have been constructed for pairs of organs found to be healthy *post-mortem.* In any case in which I had the least reason to suspect the existence of disease, the measurements have been excluded.

The following results were reached:

Healthy Organs.

TABLE IV. *Hearts with Livers.* Number 358.

Mean Heart 11·04 ozs. Standard Deviation 1·923 ozs.
Mean Liver 60·44 ozs. Standard Deviation 8·948 ozs.
Correlation of Heart and Liver ·2780 ± ·0329.

TABLE V. *Hearts with Spleens.* Number 517.

Mean Heart 11·25 ozs. Standard Deviation 2·073 ozs.
Mean Spleen 5·22 ozs. Standard Deviation 1·996 ozs.
Correlation of Heart and Spleen ·2654 ± ·0276.

TABLE VI. *Hearts with Kidneys.* Number 413.

Mean Heart 11·24 ozs. Standard Deviation 1·946 ozs.
Mean Kidney* 12·01 ozs. Standard Deviation 2·016 ozs.
Correlation of Heart and Kidneys ·4004 ± ·0279.

Drawing up a table of coefficients of variation as before we have:

TABLE B.

Relative Variability of Healthy Organs.

Organ	Coefficient of Variation
Hearts with Livers ...	17·42
Hearts with Spleens ...	18·42 } mean 17·71
Hearts with Kidneys ...	17·30
Livers	... ... 14·80
Spleens	... ... 38·21
Kidneys	... ... 16·80

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[*] The mean value of the *right* kidney of 100 males 20 to 55 years of age, as deduced by Pearson from Reid and Peacock's values, is 5·57 ozs.

From these results we infer,

(*a*) That the average "healthy" organs are all lighter than those of the average general hospital population, and probably lighter than those of the general population as a whole. The weights are still, however, higher than those given by Peacock and Reid or by Clendinning.

(*b*) In passing from the mixed hospital population to the class of healthy organs, we find in every case the absolute variability is reduced, and by very large amounts indeed, the variability of the heart by over 50 p.c., and the other organs by amounts even 30 to 40 p.c. of their value.

(*c*) Relatively, the healthy spleen is still the most variable organ, and the heart comes second, but the kidneys are now close to the heart and the liver not very far behind. Disease appears to affect the weights of heart and spleen most, of livers and kidneys least.

We notice that our value for the coefficient of variation of the healthy heart is now 17·7 as against the result deduced from Peacock and Reid's measurement of 19·8 and for the liver 14·8 as against their 14·3*. We could hardly have anticipated such good agreement, and it certainly tends to confirm the value of the coefficient of variation as a fairly "steady" biometric constant.

4. *Influence of Age on the Weights of the Viscera.*

I have first considered the change in the absolute weight of the adult male heart with age, and I have then investigated the influence of age upon one set of correlations and variabilities, i.e. those of heart and spleen.

Table VII. gives the correlation between age and weight of heart in the case of health. We deduce the following values of the constants:

TABLE VII. *Relationship of Weight of Healthy Heart to Age.* Number 699.

Mean Heart	11·13 ozs.	Standard Deviation	2·015 ozs.
Mean Age	40·23 years.	Standard Deviation	8·500 years.

Correlation of Weight of Heart with Age = ·1363 ± ·0250.

There is thus a distinctly sensible increase of heart weight in health with age, the coefficient of correlation is more than five times its probable error. Still the correlation is smaller than what we might possibly have anticipated. Calculating the regression line we have, if H_p be the probable weight of heart in ozs., and A the age in years:

$$H_p = 9{\cdot}8322 + {\cdot}0323\,A.$$

Thus the average healthy heart gains about $\frac{1}{3}$ oz. per ten years. For example we have:

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* Pearson (*The Chances of Death*, Vol. I. p. 318) gives 20·49 for the coefficient of variation of the *right* kidney as deduced from Peacock and Reid's measurements, as against my values of 16·80 for healthy and 24·63 for general hospital weights of both kidneys.

Average weight of Heart at 20 years is 10·48 ozs.
„ „ „ 30 „ „ 10·80 „
„ „ „ 40 „ „ 11·12 „
„ „ „ 50 „ „ 11·45 „
„ „ „ 60 „ „ 11·77 „ *

As far as I am aware, the correlation between age and weight of body in adult males is unknown. We should *à priori* expect it to be greater than the above, but it is always dangerous to judge without actual data. The correlation between stature and age is known, and is actually *negative*; the stature of the adult male diminishing by about $\frac{1}{3}$ inch for ten years after his prime at 28 years†. We thus conclude that while the stature decreases by $\frac{1}{3}$ unit, the heart increases by $\frac{1}{3}$ unit per ten years.

When we remember that the healthy heart is on the average much smaller than the heart in disease, and that sickness on the average increases continuously with age‡, we shall probably lay less emphasis on the general *à priori* idea that the weight of the adult heart increases very sensibly with age alone.

For my second inquiry I had unfortunately not sufficient material to divide my healthy hearts into three age groups and thus determine the influence of age on variability and correlation. I should have got less than 180 cases for each table. I was thus reluctantly compelled to deal with hearts in the general hospital population.

I divided them into three groups, ages 25—35, 35—45, and 45—55. The following results were reached:

Age Influence on Hearts and Spleens of General Hospital Population.

TABLE VIII. *Hearts and Spleens.* Ages 25—35. Number 358.

Mean Heart 11·91 ozs. Standard Deviation 3·997 ozs.
Mean Spleen 7·45 ozs. Standard Deviation 3·758 ozs.
Correlation of Heart and Spleen = ·0785 ± ·0384.

TABLE IX. *Hearts and Spleens.* Ages 35—45. Number 536.

Mean Heart 13·16 ozs. Standard Deviation 4·018 ozs.
Mean Spleen 6·60 ozs. Standard Deviation 3·428 ozs.
Correlation of Heart and Spleen = ·1817 ± ·0282.

TABLE X. *Hearts and Spleens.* Ages 45—55. Number 403.

Mean Heart 13·65 ozs. Standard Deviation 4·425 ozs.
Mean Spleen 6·21 ozs. Standard Deviation 3·120 ozs.
Correlation of Heart and Spleen = ·2518 ± ·0315.

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* Clendinning gives, Ages 15—29, 8½ ozs.; 30—50, 9½ ozs.; 50—60, 10⅙ ozs. *Med. Chirurg. Trans.* 1838. See also Peacock and Reid, *op. cit.*

† *Biometrika*, Vol. I. pp. 46–9.

‡ *Biometrika*, Vol. II. pp. 260 *et seq.*

Forming as before a table of coefficients of variation, we have:

TABLE C.

Relative Variabilities of General Hospital Population of Hearts and Spleens at different Ages.

Organ	Coefficient of Variation	Organ	Coefficient of Variation
Heart, 25—35	32·79	Spleen, 25—35	50·42
Heart, 35—45	30·53	Spleen, 35—45	51·97
Heart, 45—55	32·42	Spleen, 45—55	50·24

We can draw some important results from the above constants.

(*a*) The heart in the general hospital population of adults increases far more rapidly with age than it does in the class of healthy hearts. On the other hand the weight of the spleen sensibly decreases.

(*b*) The absolute variability of the heart increases 10 per cent., and the absolute variability of the spleen decreases 17 per cent. during the period considered. These are quite sensible changes. Thus, while the heart tends to grow larger and more variable, the spleen tends to grow smaller and less variable.

(*c*) If we deal with relative variation as judged by the coefficient of variation, we see that the changes referred to under (*a*) and (*b*) almost balance each other. Or, the relative variabilities of both heart and spleen remain sensible constants with age and equal to the values found for the general hospital population of adults of all ages in Table A, p. 66. This is further evidence of the real value of the coefficient of variation as a biometric measure of variability.

(*d*) The correlation between heart and spleen steadily increases with age. In the first period it is comparatively small, in the second period it has much the same value as in the general hospital population of adults (see p. 65), and in the third period it approaches the value found for healthy adults.

These results are quite reasonable. As death below the age of 35 is generally abnormal*, we should expect to find that the coefficient of correlation was low. Over the age of 45 years there is a slow deterioration of all organs. There is no evidence to show that this degeneration is much more acute in any one of the organs we are considering than in any other. Therefore, although the absolute weights will differ from the normal, the correlation may be the same, and this we see that it actually is.

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* By "abnormal" is meant here a death due to disease; the result of an accident would be from this point of view a normal death, as probably leaving the viscera "healthy" under *post-mortem* record.

5. *Influence of Special Diseases on the Cardiac Biometric Constants.*

We are now in a position to consider the effect of some special diseases on the weight and correlations of the heart. Unfortunately, scantiness of material and pressure on my time hindered my developing this most interesting branch of my subject very fully in the present paper. I shall hope to give it further consideration in another communication. I have confined my attention here to the heart and spleen weights, variabilities, and correlations in the case of two disease groups. First, Pneumonia (excluding tubercular disease); secondly, Valvular Disease of the Heart and Aortic Aneurism. I regret that the total number of cases available is small.

TABLE XI. *Hearts and Spleens. Cases of Pneumonia.* Number 177.

Mean Heart 12·50 ozs. Standard Deviation 2·768 ozs.
Mean Spleen 6·59 ozs. Standard Deviation 2·842 ozs.
Correlation of Heart and Spleen = ·1065 ± ·0501.

TABLE XII. *Hearts and Spleens. Cases of Valvular Disease and Aortic Aneurism.* Number 166.

Mean Heart 19·08 ozs. Standard Deviation 5·950 ozs.
Mean Spleen 8·57 ozs. Standard Deviation 5·158 ozs.
Correlation = ·0552 ± ·0522.

Forming as before a table for relative variabilities:

TABLE D.

Relative Variabilities of Heart and Spleen under Special Diseases.

Disease	Organ	Coefficient of Variation
Pneumonia	Heart	22·15
Valvular Disease and Aortic Aneurism	Heart	31·18
Pneumonia	Spleen	43·12
Valvular Disease and Aortic Aneurism	Spleen	60·16

From these values of the constants we may draw the following conclusions:

(*a*) In cases of pneumonia the mean weight of the heart is above that of the healthy heart (p. 67), but slightly below that of the general hospital population heart (p. 65). The weight of the spleen is somewhat above that of the healthy spleen (p. 67), and only about equal to that of the general hospital population spleen (p. 65). The absolute variabilities of both heart and spleen in pneumonia are far lower than the values in the general hospital population, and only slightly higher than their values in the case of healthy organs. The same remark applies to relative variabilities, which are in the case of this disease somewhat higher than the healthy values, but considerably below those of the general hospital population. We must therefore conclude that pneumonia does not influence in a *marked* degree the average values or the variabilities of either heart or spleen weights. As it does raise the variability somewhat, i.e. introduces disturbances in the relationship, we are not surprised to find that it weakens, although again not in a very marked degree, the correlation between weights of heart and spleen.

(*b*) On the other hand, Valvular Disease and Aortic Aneurism send up the weights of *both* heart and spleen not only vastly above their healthy values, but markedly above the values for the general hospital population. Further, their absolute variabilities are increased considerably above the general hospital population values, and *à fortiori* above the healthy values. The coefficients of variation of both are also far above the values in health, and that for the spleen above the general hospital values. In the case of the heart, the mean has been sent up so high that although the absolute variability is considerably greater, the relative variability remains much the same. The general effect of these heart diseases is to render the correlation between heart and spleen hardly sensible.

If we may judge by these two cases the general effect of disease is to increase the variability of affected organs and reduce their correlation. This is absolutely in keeping with the sensible, but of course less marked, changes we find when we pass from a population with healthy organs to the general hospital population, which of course contains much disease.

6. *General Conclusions.*

The present paper is chiefly intended as an illustration of how effective biometric methods might be from the standpoint of medical science if only there were a systematic collection on a large scale of normal and pathological data. Some definite conclusions, however, may yet be drawn, and some suggestions made on the basis of our numbers. We see sensible, if moderate, correlations between the weights of heart, liver, spleen, and kidneys.

It may be somewhat difficult to understand why the heart-kidney correlation is higher than that of the heart with any of the other organs. That the kidney should be more closely associated with the heart than the liver is possibly owing to its more subordinate functions. The liver is the seat of so many important processes that its immediate connection with the heart is not so great as that of the heart with the kidney. The excretion of fluids is so closely bound up with physical changes in the vascular system, and conversely changes in renal structure react so markedly upon the heart and blood vessels that a very close physical relationship appears probable. No doubt the liver is greatly affected in many forms of cardiac disease, but on the other hand serious functional disturbances or even acute inflammation of the liver do not produce heart changes with the same precision as analogous mischief in the kidney does. If this partially and imperfectly accounts for the higher heart-kidney correlation as compared with the heart-liver coefficient, it may perhaps serve as an argument in the case of the spleen. Heart mischief nearly always reacts on the spleen, but splenic trouble does not always affect the heart.

If we consider in broad lines the general results of our investigation, we should say that they may be summed up in the statement that both special diseases and the general want of health to be found in a hospital population tend in the same directions, namely, to increase the variability of the organs dealt with and to reduce their correlation. As we pass from the general hospital population to a healthy population we find that variability sinks and correlation rises. To what extent this is an antecedent or concomitant of the diseased state it might not be always possible to assert.

In taking any population, low variabilities and high correlations are the two factors which measure closeness to type. As a general rule, under a given environment closeness to type is a condition of stability, we may almost say, of low selective death-rate. Hence we may look upon disease as less stringent approach to type, and high variability and low correlation as a sign of instability*.

Of course the capacity to vary absolutely and to alter the relationship of organs must exist, or a race will not be able to effect a change in type with a changing environment. Still, if we trust the theory of correlation by natural selection at all, death before senility as far as it is selective is the destruction of the less fit, i.e. of those not approaching within certain limits the type suitable to the environment. Thus it comes about that we shall expect on the Darwinian theory to find the individuals who die of disease in adult life to be more variable and less highly correlated in their organs than the "healthy." This is precisely what we do find, and the *post-mortem* room provides direct evidence in favour of the action of natural selection in the case of man. Indeed, in a not very conscious way the medical world has been expressing these very truths of evolution in other words. The figures we have considered showing lowered correlation in the diseased state are a biometric illustration of the truth of Dr Sutton's aphorism, "Disease is absence of rhythm†." In the normal or healthy group we see a population possessing the characteristic marks of stability, small variability, and high correlation. In the two special and the general diseased groups we have conditions tending in the opposite sense. In the healthy class we get a closer quantitative relationship between the weights of the viscera, in the diseased there is greater variety of proportions. Indeed, to adopt a well-worn definition, "Among the diseased each organ has a life and growth of its own, irrespective of the needs of the organism as a whole." Our biometric investigation shows us this independent life and growth leading to increased variability and to lessened correlation, shortly, to those deviations from type which beyond certain limits are incompatible with survival under a given environment‡.

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* In the evolution of subspecies it seems probable that the hardiest and most prolific groups have the least coefficients of variation. Thus in an investigation recently made by Mr A. Bacot and the author on the variability of *Spilosoma Urticae*, it was found that in several series of broods the groups with the largest coefficients of variation had the least net fertility.

† *Medical Pathology*, 1886, p. 95 *et seq.*

‡ I desire to take this opportunity of expressing my gratitude to Prof. Karl Pearson, to whose staff, among other acts of kindness, I owe the correction of many arithmetical slips in the above results. Anything of interest in this essay is due, either directly or indirectly, to him.

TABLE I.

General Hospital Population. Males. Hearts and Livers.

Hearts in ozs.

Livers in ozs.	5·125— 6·125	6·125— 7·125	7·125— 8·125	8·125— 9·125	9·125—10·125	10·125—11·125	11·125—12·125	12·125—13·125	13·125—14·125	14·125—15·125	15·125—16·125	16·125—17·125	17·125—18·125	18·125—19·125	19·125—20·125	20·125—21·125	21·125—22·125	22·125—23·125	23·125—24·125	24·125—25·125	25·125—26·125	26·125—27·125	27·125—28·125	28·125—29·125	29·125—30·125	30·125—31·125	31·125—32·125	32·125—33·125	33·125—34·125	34·125—35·125	35·125—36·125	Totals
28·125— 32·125	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
32·125— 36·125	1	—	1	—	5	1	2	2	—	—	—	—	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16
36·125— 40·125	1	2	5	5	4	4	1	—	1	—	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	27
40·125— 44·125	4	1	2	8	5	4	3	5	2	2	1	—	—	1	—	1	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	41
44·125— 48·125	—	3	5	9	11	13	3	4	4	1	4	2	5	1	1	—	3	—	1	2	—	1	—	—	—	—	—	—	—	—	—	73
48·125— 52·125	2	1	4	13	18	15	19	6	9	4	5	—	2	3	5	3	1	—	2	1	—	—	—	—	—	—	—	—	—	—	—	113
52·125— 56·125	—	4	7	7	19	15	26	28	8	10	12	4	3	4	2	1	4	3	6	—	2	3	—	—	—	—	—	—	—	1	1	170
56·125— 60·125	—	3	9	12	19	23	17	17	14	17	14	2	13	5	2	2	1	3	1	1	1	1	—	—	1	—	—	—	—	—	—	178
60·125— 64·125	—	—	5	8	24	30	22	17	18	15	12	4	5	5	8	—	2	3	3	1	2	—	—	—	—	1	—	—	—	—	—	185
64·125— 68·125	—	4	3	5	10	21	22	24	14	2	8	4	5	3	5	—	3	1	1	1	—	1	1	1	—	—	—	—	—	—	—	139
68·125— 72·125	—	—	4	3	12	12	19	8	12	7	15	4	4	5	2	1	2	6	1	2	—	—	2	—	—	—	1	—	1	—	—	123
72·125— 76·125	—	2	—	2	9	5	13	9	16	7	12	4	2	3	2	1	1	—	1	1	1	—	2	—	—	—	—	1	2	—	—	96
76·125— 80·125	—	—	1	2	7	12	10	7	10	3	7	3	3	1	3	1	1	—	2	—	1	1	—	—	—	—	—	—	—	—	—	75
80·125— 84·125	—	1	—	1	5	1	7	—	7	2	3	3	—	3	—	1	1	—	—	—	1	1	—	1	—	—	—	—	—	—	—	38
84·125— 88·125	—	—	—	—	1	4	4	6	5	6	1	1	2	1	1	2	—	1	3	—	—	—	—	2	—	—	—	1	—	—	—	41
88·125— 92·125	—	—	—	1	—	2	4	—	4	5	1	3	1	—	—	—	—	—	2	—	—	2	—	—	—	—	1	—	—	—	—	26
92·125— 96·125	—	—	2	—	2	—	3	4	—	1	1	1	—	—	—	—	1	—	1	—	—	—	—	—	—	—	1	—	—	—	—	17
96·125—100·125	—	—	—	—	—	—	6	5	2	—	—	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16
100·125—104·125	—	—	—	—	—	—	1	1	1	1	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	7
Totals ...	8	22	48	76	151	162	182	143	127	83	98	37	50	36	33	13	21	17	24	9	8	11	6	4	1	1	4	2	3	1	1	1382

TABLE II.

General Hospital Population. Males. Hearts and Spleens.

Hearts in ozs.

Spleens in ozs.	*5·125— 6·125*	*6·125— 7·125*	*7·125— 8·125*	*8·125— 9·125*	*9·125—10·125*	*10·125—11·125*	*11·125—12·125*	*12·125—13·125*	*13·125—14·125*	*14·125—15·125*	*15·125—16·125*	*16·125—17·125*	*17·125—18·125*	*18·125—19·125*	*19·125—20·125*	*20·125—21·125*	*21·125—22·125*	*22·125—23·125*	*23·125—24·125*	*24·125—25·125*	*25·125—26·125*	*26·125—27·125*	*27·125—28·125*	Totals
1·125— 2·125	2	2	3	4	3	4	4	2	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	27
2·125— 3·125	1	4	6	9	16	15	9	8	3	1	3	—	2	—	2	—	1	—	1	—	—	1	—	82
3·125— 4·125	5	3	7	20	26	21	19	19	13	14	13	3	7	1	2	2	2	1	—	—	—	2	—	180
4·125— 5·125	—	4	5	17	34	26	24	18	23	12	17	4	6	2	3	5	1	1	3	1	—	2	—	208
5·125— 6·125	—	3	10	12	24	37	36	23	22	6	16	6	7	7	7	1	2	3	6	—	—	1	2	231
6·125— 7·125	—	—	1	5	21	16	16	12	7	8	7	2	3	5	6	—	2	1	3	2	1	1	—	119
7·125— 8·125	—	—	4	4	11	14	23	18	12	9	13	8	6	3	5	—	3	2	3	1	—	2	—	141
8·125— 9·125	—	1	2	3	5	13	11	10	9	9	3	2	4	1	2	—	1	1	—	1	1	—	1	80
9·125—10·125	—	—	1	1	7	5	12	8	9	5	5	1	5	1	4	1	2	—	1	2	1	1	—	72
10·125—11·125	—	—	1	4	4	2	2	—	5	1	—	2	2	—	1	—	2	—	1	1	—	1	—	29
11·125—12·125	—	1	—	2	6	1	7	4	3	5	2	1	1	2	—	1	—	1	2	—	2	—	—	41
12·125—13·125	—	—	—	—	—	3	1	2	1	3	1	1	—	—	—	—	—	1	—	—	—	—	2	15
13·125—14·125	—	—	1	—	2	3	6	1	2	—	4	—	1	1	—	—	—	—	1	—	—	—	—	22
14·125—15·125	—	—	2	1	1	1	—	—	—	1	2	2	2	—	1	—	—	—	—	—	1	—	—	14
15·125—16·125	—	1	1	—	1	1	5	2	1	—	1	1	1	3	1	—	1	—	—	—	—	—	—	20
16·125—17·125	—	—	1	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
17·125—18·125	—	—	—	—	1	1	2	—	—	1	—	—	1	—	1	1	—	1	1	—	—	—	—	10
18·125—19·125	—	—	—	—	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
19·125—20·125	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
20·125—21·125	—	—	—	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
21·125—22·125	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
22·125—23·125	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Totals ...	8	19	45	83	162	166	181	127	114	76	88	33	48	26	35	11	17	12	22	8	6	11	5	1303

TABLE III.

General Hospital Population. Males. Hearts and Kidneys.

Hearts in ozs.

Kidneys in ozs.

	6·125— 7·125	*7·125— 8·125*	*8·125— 9·125*	*9·125—10·125*	*10·125—11·125*	*11·125—12·125*	*12·125—13·125*	*13·125—14·125*	*14·125—15·125*	*15·125—16·125*	*16·125—17·125*	*17·125—18·125*	*18·125—19·125*	*19·125—20·125*	*20·125—21·125*	*21·125—22·125*	*22·125—23·125*	*23·125—24·125*	*24·125—25·125*	*25·125—26·125*	*26·125—27·125*	*27·125—28·125*	Totals
6·125— 7·125	2	2	2	3	4	1	2	1	—	1	—	1	2	1	—	—	—	—	1	1	—	—	24
7·125— 8·125	4	—	7	7	5	6	5	2	—	4	—	3	3	1	—	—	—	1	—	—	—	—	48
8·125— 9·125	3	6	7	11	6	5	5	2	4	2	1	2	1	3	2	1	1	1	—	—	2	1	66
9·125—10·125	2	11	11	13	29	14	9	9	4	9	3	2	1	1	1	4	—	2	—	1	—	—	126
10·125—11·125	4	2	15	34	25	20	9	5	4	3	2	2	2	1	2	1	2	—	—	1	1	—	135
11·125—12·125	4	7	16	24	38	34	26	16	15	8	4	8	5	2	1	2	—	1	1	1	—	1	214
12·125—13·125	2	2	9	23	20	20	19	20	4	12	4	6	3	3	1	1	1	2	1	—	—	—	153
13·125—14·125	—	4	8	13	16	28	20	14	12	10	7	5	4	7	1	1	5	7	2	—	4	—	168
14·125—15·125	—	1	5	12	5	16	11	17	6	10	2	3	1	6	1	2	3	1	2	—	—	—	104
15·125—16·125	—	3	2	10	10	13	11	12	7	13	2	7	1	—	2	2	—	2	—	1	1	3	102
16·125—17·125	—	—	1	3	4	11	6	2	4	8	4	2	—	—	—	1	—	1	—	—	—	—	47
17·125—18·125	—	1	1	3	3	3	7	8	2	3	—	3	3	2	—	—	1	3	—	—	—	—	43
18·125—19·125	—	—	—	2	3	1	1	2	2	1	3	—	—	2	—	1	1	1	—	1	—	—	21
19·125—20·125	—	—	—	2	1	3	3	1	1	—	1	1	—	1	—	—	1	1	1	—	—	—	17
20·125—21·125	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	1	—	—	—	3
21·125—22·125	—	—	—	—	1	—	—	—	2	1	1	—	—	1	—	—	—	1	—	—	—	—	7
22·125—23·125	—	—	—	—	—	—	—	1	1	—	2	1	—	1	—	—	1	—	—	—	—	—	7
23·125—24·125	—	—	—	—	—	1	1	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	4
24·125—25·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25·125—26·125	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	2
26·125—27·125	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
27·125—28·125	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
Totals ...	21	39	84	160	170	177	135	112	69	88	37	46	27	32	11	17	16	24	9	6	8	5	1293

TABLE IV.

Healthy Hearts and Livers. Males.

Hearts in ozs.

Livers in ozs.	*7·125— 8·125*	*8·125— 9·125*	*9·125—10·125*	*10·125—11·125*	*11·125—12·125*	*12·125—13·125*	*13·125—14·125*	*14·125—15·125*	*15·125—16·125*	Totals
44·125—48·125	3	5	3	5	3	2	1	—	—	22
48·125—52·125	2	12	13	10	7	3	3	2	2	54
52·125—56·125	3	8	15	6	10	9	1	1	—	53
56·125—60·125	6	8	11	13	7	6	4	3	3	61
60·125—64·125	2	3	12	9	10	2	7	2	1	48
64·125—68·125	1	3	3	13	13	6	5	1	—	45
68·125—72·125	1	1	4	4	7	4	2	1	2	26
72·125—76·125	—	1	1	4	5	6	7	1	2	27
76·125—80·125	—	1	3	6	3	3	5	1	—	22
Totals ...	18	42	65	70	65	41	35	12	10	358

TABLE V.

Healthy Hearts and Spleens. Males.

Hearts in ozs.

Spleens in ozs.	*7·125— 8·125*	*8·125— 9·125*	*9·125—10·125*	*10·125—11·125*	*11·125—12·125*	*12·125—13·125*	*13·125—14·125*	*14·125—15·125*	*15·125—16·125*	*16·125—17·125*	Totals
1·125— 2·125	4	3	3	2	2	1	2	1	—	—	18
2·125— 3·125	6	7	12	9	6	5	1	—	—	—	46
3·125— 4·125	6	15	21	16	14	10	6	11	2	—	101
4·125— 5·125	1	12	25	18	15	11	13	3	5	1	104
5·125— 6·125	5	8	16	27	24	13	13	—	5	—	111
6·125— 7·125	1	5	9	4	10	9	2	2	2	—	44
7·125— 8·125	—	2	7	8	6	11	8	4	6	1	53
8·125— 9·125	—	1	2	7	1	3	1	1	—	1	17
9·125—10·125	—	—	—	1	5	—	2	2	3	—	13
10·125—11·125	—	2	1	1	—	—	—	—	—	—	4
11·125—12·125	—	—	—	—	2	1	1	1	—	1	6
Totals ...	23	55	96	93	85	64	49	25	23	4	517

TABLE VI.

Healthy Hearts and Kidneys. Males.

Hearts in ozs.

Kidneys in ozs.	*7·125— 8·125*	*8·125— 9·125*	*9·125—10·125*	*10·125—11·125*	*11·125—12·125*	*12·125—13·125*	*13·125—14·125*	*14·125—15·125*	*15·125—16·125*	Totals
7·125— 8·125	1	3	—	2	2	1	—	—	—	9
8·125— 9·125	1	6	5	1	3	1	—	—	—	17
9·125—10·125	7	7	6	14	6	4	3	1	1	49
10·125—11·125	2	8	23	17	11	4	2	2	1	70
11·125—12·125	1	5	11	22	19	12	7	3	1	81
12·125—13·125	1	4	17	12	11	13	8	1	1	68
13·125—14·125	3	2	8	7	12	9	7	4	2	54
14·125—15·125	1	—	4	3	5	5	8	2	5	33
15·125—16·125	1	1	1	1	4	2	7	4	3	24
16·125—17·125	—	—	—	1	2	1	—	2	1	7
17·125—18·125	—	—	—	—	1	—	—	—	—	1
Totals ...	18	36	75	80	76	52	42	19	15	413

TABLE VII.

Correlation of Age and Heart Weight. Healthy Males.

Hearts in ozs.

Ages. Years	*7·125— 8·125*	*8·125— 9·125*	*9·125—10·125*	*10·125—11·125*	*11·125—12·125*	*12·125—13·125*	*13·125—14·125*	*14·125—15·125*	*15·125—16·125*	*16·125—17·125*	Totals
*25*th and *26*th	3	4	7	6	3	2	5	1	—	—	31
*27*th and *28*th	3	9	10	9	8	3	1	2	—	—	45
*29*th and *30*th	3	6	10	9	12	7	2	1	1	—	51
*31*st and *32*nd	4	7	9	9	6	4	6	—	—	—	45
*33*rd and *34*th	5	4	9	14	7	7	2	3	3	—	54
*35*th and *36*th	2	6	4	11	10	8	1	1	3	—	46
*37*th and *38*th	3	7	10	6	10	5	2	1	4	1	49
*39*th and *40*th	—	5	13	13	16	10	4	1	3	—	65
*41*st and *42*nd	—	3	11	4	7	8	4	3	3	—	43
*43*rd and *44*th	—	3	8	4	8	3	6	—	2	—	34
*45*th and *46*th	4	4	13	7	10	5	8	3	3	—	57
*47*th and *48*th	1	3	7	4	5	7	4	1	—	—	32
*49*th and *50*th	1	7	13	5	5	7	5	6	—	1	50
*51*st and *52*nd	3	4	7	7	6	2	6	4	3	—	42
*53*rd and *54*th	—	4	8	13	7	7	4	—	3	1	47
*55*th and *56*th	1	1	1	—	2	1	1	1	—	—	8
Totals ...	33	77	140	121	122	86	61	28	28	3	699

TABLE VIII.

Hearts and Spleens. General Hospital Population. Males. Young Adults (25—35 years).

Hearts in ozs.

Spleens in ozs.	*5·125— 6·125*	*6·125— 7·125*	*7·125— 8·125*	*8·125— 9·125*	*9·125—10·125*	*10·125—11·125*	*11·125—12·125*	*12·125—13·125*	*13·125—14·125*	*14·125—15·125*	*15·125—16·125*	*16·125—17·125*	*17·125—18·125*	*18·125—19·125*	*19·125—20·125*	*20·125—21·125*	*21·125—22·125*	*22·125—23·125*	*23·125—24·125*	*24·125—25·125*	*25·125—26·125*	*26·125—27·125*	*27·125—28·125*	Totals
1·125— 2·125	—	1	—	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4
2·125— 3·125	1	1	2	1	6	3	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16
3·125— 4·125	2	1	4	5	6	6	6	3	2	1	2	—	—	—	—	1	—	—	—	—	—	—	—	39
4·125— 5·125	—	1	1	7	5	7	6	5	4	5	2	—	—	1	—	2	—	—	—	—	—	—	—	46
5·125— 6·125	—	—	5	3	6	9	9	5	8	1	3	1	3	1	—	—	2	—	2	—	—	—	1	59
6·125— 7·125	—	—	—	2	10	5	7	2	1	2	1	1	—	1	—	—	—	—	—	1	1	1	—	35
7·125— 8·125	—	—	1	5	5	7	11	5	—	2	2	1	1	1	1	—	—	—	1	1	—	—	—	44
8·125— 9·125	—	—	1	2	2	5	1	4	1	—	1	—	1	—	—	—	—	—	—	1	1	—	—	20
9·125—10·125	—	1	—	1	6	4	4	3	1	1	2	—	—	—	1	—	1	—	—	1	—	—	—	26
10·125—11·125	—	—	—	1	3	—	—	—	3	1	—	1	1	—	—	—	—	—	1	—	—	1	—	12
11·125—12·125	—	1	—	1	3	1	3	3	2	2	1	—	—	—	—	—	—	—	—	—	—	—	—	17
12·125—13·125	—	—	—	—	—	2	1	—	—	1	—	—	—	—	—	—	—	1	1	—	—	—	1	7
13·125—14·125	—	—	1	—	—	2	2	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	6
14·125—15·125	—	—	2	1	2	—	—	—	—	—	1	2	1	—	—	—	—	—	—	—	—	—	—	9
15·125—16·125	—	—	—	—	1	1	2	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	5
16·125—17·125	—	—	1	—	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
17·125—18·125	—	—	—	1	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
18·125—19·125	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
19·125—20·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20·125—21·125	—	—	—	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
21·125—22·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22·125—23·125	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
23·125—24·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Totals ...	3	6	18	32	56	56	57	31	25	16	16	6	7	5	2	3	3	1	5	4	2	2	2	358

TABLE IX.

Hearts and Spleens. General Hospital Population. Males. Prime of Life (35—45 *years*).

Hearts in ozs.

Spleens in ozs.	*5·125— 6·125*	*6·125— 7·125*	*7·125— 8·125*	*8·125— 9·125*	*9·125—10·125*	*10·125—11·125*	*11·125—12·125*	*12·125—13·125*	*13·125—14·125*	*14·125—15·125*	*15·125—16·125*	*16·125—17·125*	*17·125—18·125*	*18·125—19·125*	*19·125—20·125*	*20·125—21·125*	*21·125—22·125*	*22·125—23·125*	*23·125—24·125*	*24·125—25·125*	*25·125—26·125*	*26·125—27·125*	*27·125—28·125*	*28·125—29·125*	Totals
1·125— 2·125	1	2	1	1	3	2	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12
2·125— 3·125	—	—	3	5	5	6	6	5	2	—	2	—	1	—	1	—	—	—	—	—	—	—	—	—	36
3·125— 4·125	1	2	1	6	8	7	7	12	6	5	8	1	4	—	2	1	2	1	—	—	—	—	—	—	74
4·125— 5·125	—	2	3	6	16	10	11	10	9	4	8	1	3	—	2	2	2	2	2	1	—	2	—	—	96
5·125— 6·125	—	2	2	6	10	18	16	6	6	4	4	2	1	3	3	1	1	—	—	—	—	—	—	—	85
6·125— 7·125	—	—	—	1	7	9	3	7	5	3	3	1	3	2	2	—	3	1	—	—	—	—	—	—	50
7·125— 8·125	—	—	—	1	4	5	8	3	8	3	3	5	2	2	2	—	1	2	2	—	—	—	—	—	51
8·125— 9·125	—	1	1	—	—	4	9	5	4	5	1	2	2	—	1	—	—	—	—	—	—	—	—	—	35
9·125—10·125	—	—	1	2	2	—	4	4	5	3	4	—	1	—	1	—	1	—	1	—	1	—	—	—	30
10·125—11·125	—	—	1	2	1	1	2	—	1	1	1	—	—	—	1	—	—	—	—	1	—	—	—	—	12
11·125—12·125	—	—	—	1	2	—	2	1	—	—	2	1	1	—	—	—	—	1	—	—	1	—	—	1	13
12·125—13·125	—	—	—	—	—	1	—	1	1	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	5
13·125—14·125	—	—	—	—	1	1	4	1	2	—	2	—	1	—	—	—	—	—	—	—	—	—	—	—	12
14·125—15·125	—	—	—	—	—	1	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	3
15·125—16·125	—	1	1	—	—	—	1	2	—	—	1	1	—	1	1	—	1	—	—	—	—	—	—	—	10
16·125—17·125	—	—	1	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
17·125—18·125	—	—	—	—	—	1	—	—	—	1	—	—	1	—	1	—	—	1	1	—	—	—	—	—	6
18·125—19·125	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
19·125—20·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20·125—21·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
21·125—22·125	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Totals ...	2	10	15	31	59	67	76	58	50	31	39	15	20	8	18	4	11	8	6	2	2	2	1	1	536

TABLE X.

Hearts and Spleens. General Hospital Population. Males. Middle Age (45—55 years).

Hearts in ozs.

Spleens in ozs.	*5·125— 6·125*	*6·125— 7·125*	*7·125— 8·125*	*8·125— 9·125*	*9·125—10·125*	*10·125—11·125*	*11·125—12·125*	*12·125—13·125*	*13·125—14·125*	*14·125—15·125*	*15·125—16·125*	*16·125—17·125*	*17·125—18·125*	*18·125—19·125*	*19·125—20·125*	*20·125—21·125*	*21·125—22·125*	*22·125—23·125*	*23·125—24·125*	*24·125—25·125*	*25·125—26·125*	*26·125—27·125*	*27·125—28·125*	*28·125—29·125*	Totals
1·125— 2·125	1	1	3	2	2	1	3	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15
2·125— 3·125	—	1	1	3	6	5	3	1	—	—	1	—	1	—	—	—	2	—	1	—	—	1	—	—	26
3·125— 4·125	—	—	1	9	10	7	4	7	6	7	3	1	3	1	—	—	—	—	—	—	—	1	—	—	60
4·125— 5·125	—	1	1	4	15	9	5	4	10	4	8	4	1	1	1	—	—	—	1	—	—	1	—	—	70
5·125— 6·125	—	2	2	—	6	10	12	10	6	2	7	2	3	3	3	—	—	1	3	—	—	1	1	—	74
6·125— 7·125	—	—	1	2	3	2	6	3	2	1	4	1	—	2	4	—	—	—	4	1	—	—	—	—	36
7·125— 8·125	—	—	2	—	2	3	6	10	2	4	5	2	3	1	2	—	—	—	—	—	—	1	—	—	43
8·125— 9·125	—	—	—	—	2	4	1	—	4	2	—	—	1	1	—	—	1	1	—	—	—	1	1	—	19
9·125—10·125	—	—	—	—	—	1	4	1	3	—	—	1	4	1	1	1	1	—	—	1	—	—	—	1	20
10·125—11·125	—	—	—	1	—	1	—	—	1	—	—	1	1	—	—	—	1	—	—	—	—	—	—	—	6
11·125—12·125	—	—	—	—	—	—	2	1	1	3	—	1	—	2	—	1	—	—	2	—	1	—	—	—	14
12·125—13·125	—	—	—	—	—	—	—	1	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	4
13·125—14·125	—	—	—	—	1	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	3
14·125—15·125	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—	—	3
15·125—16·125	—	—	—	—	1	—	2	1	—	—	1	—	1	—	1	—	—	—	—	—	—	—	—	—	7
16·125—17·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17·125—18·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
18·125—19·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19·125—20·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20·125—21·125	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Totals ...	1	6	11	21	49	43	49	39	37	25	32	13	18	13	12	3	5	2	11	2	2	6	2	1	403

TABLE XI.

Correlation of Hearts and Spleens in Pneumonia. Males. (Cases of Pneumonia with Valvular Disease of Heart and Tubercular Pneumonia are excluded.)

Hearts in ozs.

Spleens in ozs.	*6·125— 7·125*	*7·125— 8·125*	*8·125— 9·125*	*9·125—10·125*	*10·125—11·125*	*11·125—12·125*	*12·125—13·125*	*13·125—14·125*	*14·125—15·125*	*15·125—16·125*	*16·125—17·125*	*17·125—18·125*	*18·125—19·125*	*19·125—20·125*	....	*26·125—27·125*	Totals
1·125— 2·125	—	—	1	—	1	1	—	—	—	—	—	—	—	—	...	—	3
2·125— 3·125	—	—	1	1	2	—	—	—	—	—	—	1	—	—	...	—	5
3·125— 4·125	1	—	1	4	4	1	3	4	2	1	—	—	—	—	...	—	21
4·125— 5·125	—	—	2	2	3	4	3	2	5	2	—	—	—	—	...	—	23
5·125— 6·125	—	1	—	5	6	9	8	4	2	3	1	—	1	1	...	1	42
6·125— 7·125	—	—	—	6	4	2	4	2	—	1	1	—	2	3	...	—	25
7·125— 8·125	—	—	—	2	5	4	3	2	—	2	—	—	—	1	...	—	19
8·125— 9·125	—	—	—	—	1	5	3	2	1	1	—	1	—	—	...	—	14
9·125—10·125	—	—	1	1	1	3	2	2	—	—	—	1	—	—	...	—	11
10·125—11·125	—	—	1	—	1	—	—	—	—	—	—	—	—	—	...	—	2
11·125—12·125	—	—	—	—	—	1	—	—	1	—	—	—	—	—	...	—	2
12·125—13·125	—	—	—	—	—	—	1	—	—	—	—	—	—	—	...	—	1
13·125—14·125	—	—	—	—	—	3	—	1	—	—	—	—	—	—	...	—	4
14·125—15·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	—
15·125—16·125	—	—	—	—	—	2	—	—	—	—	—	—	1	—	...	—	3
16·125—17·125	—	—	—	—	—	—	—	1	—	—	—	—	—	—	...	—	1
17·125—18·125	—	—	—	—	—	—	—	—	1	—	—	—	—	—	...	—	1
Totals ...	1	1	7	21	28	35	27	20	12	10	2	3	4	5	...	1	177

TABLE XII.

Correlation of Hearts and Spleens in Valvular Disease of Heart and Aortic Aneurism. Males.

Hearts in ozs.

Spleens in ozs.

	8·125— 9·125	9·125—10·125	10·125—11·125	11·125—12·125	12·125—13·125	13·125—14·125	14·125—15·125	15·125—16·125	16·125—17·125	17·125—18·125	18·125—19·125	19·125—20·125	20·125—21·125	21·125—22·125	22·125—23·125	23·125—24·125	24·125—25·125	25·125—26·125	26·125—27·125	27·125—28·125	28·125—29·125	29·125—30·125	30·125—31·125	31·125—32·125	32·125—33·125	33·125—34·125	34·125—35·125	35·125—36·125	....	44·125—45·125	Totals
1·125— 2·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	—
2·125— 3·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	...	—	1
3·125— 4·125	1	1	—	2	—	1	2	1	1	2	1	1	2	2	—	—	—	—	1	—	—	—	—	—	—	—	—	1	...	—	19
4·125— 5·125	1	—	2	—	1	2	1	1	—	2	1	3	2	1	1	1	1	—	1	—	—	—	—	—	—	1	—	—	...	—	22
5·125— 6·125	—	—	—	—	2	1	2	1	1	3	1	4	—	2	1	2	—	—	—	2	—	—	—	—	—	—	—	1	...	—	23
6·125— 7·125	—	—	—	1	2	1	1	3	—	—	—	3	—	2	—	2	2	1	1	—	—	—	1	—	—	—	—	—	...	1	21
7·125— 8·125	—	—	—	2	1	1	—	—	2	2	2	2	—	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	...	—	15
8·125— 9·125	—	—	1	2	—	—	3	—	1	2	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	...	—	11
9·125—10·125	—	—	—	—	1	—	—	2	1	4	—	1	—	2	—	1	—	—	—	—	1	1	—	—	—	1	—	—	...	—	15
10·125—11·125	—	—	—	—	—	1	—	—	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	4
11·125—12·125	—	1	—	1	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	...	—	5
12·125—13·125	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	...	—	3
13·125—14·125	—	—	—	1	—	—	—	2	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	6
14·125—15·125	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	—	...	—	4
15·125—16·125	—	—	—	—	—	—	—	—	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	3
16·125—17·125	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	1
17·125—18·125	—	—	—	1	—	—	—	—	—	1	—	1	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	...	—	5
18·125—19·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	—
19·125—20·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	...	—	1
20·125—21·125	—	—	—	1	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	3
....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25·125—26·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	...	—	1
26·125—27·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	—
27·125—28·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	—
28·125—29·125	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	1
29·125—30·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	...	—	1
30·125—31·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	—
31·125—32·125	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	...	—	1
Totals ...	2	2	3	11	7	8	9	12	11	20	7	18	6	9	4	10	4	3	4	3	2	2	1	2	1	2	—	2	...	1	166

SUI MASSIMI DELLE CURVE DIMORFICHE.

DAL DR FERNANDO DE HELGUERO, Roma.

SOMMARIO.

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1. *Introduzione.*

È ben nota la importanza che ha nella Biometrica la curva detta *normale* avente l' equazione in coordinate cartesiane ortogonali:

$$y = y_0 e^{-\frac{(x-b)^2}{2\sigma^2}}.$$

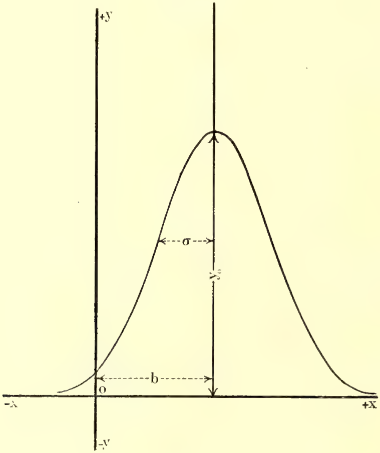

FIG. 1.

Essa ha tre parametri: y_0, b, σ, pei quali adotteremo le denominazioni di *ordinata massima* (y_0), *media* (b) e *deviazione normale* (standard deviation) (σ): le y_0 e σ sono sempre positive.

La sua forma è nota (Vedi fig. 1): in un piano cartesiano di assi $y=0$, $x=0$ essa giace intieramente dalla parte delle y positive, è simmetrica rispetto alla retta $x=b$ che dicesi *asse della curva normale.* La y è massima per $x=b$ ed ha il valore y_0, va da ambe le parti decrescendo continuamente fino a rendersi asintotica all' asse delle x, che dicesi *base della curva.* Esistono inoltre due flessi corrispondenti alle ascisse $b \pm \sigma$.

Si è trovato che questa curva serve ad esprimere le variazioni di molti caratteri in gruppi omogenei di organismi. Se invece si considera un materiale eterogeneo, risultante dalla mescolanza di due gruppi omogenei, si ottengon delle curve di frequenza dette *dimorfiche,* osservate per la prima volta dal Livi*. Queste posson graficamente ottenersi tracciando sulla stessa base due curve normali e su ogni ordinata prendendo la somma delle frequenze corrispondenti alle due curve (Vedi fig. 2). La loro equazione è

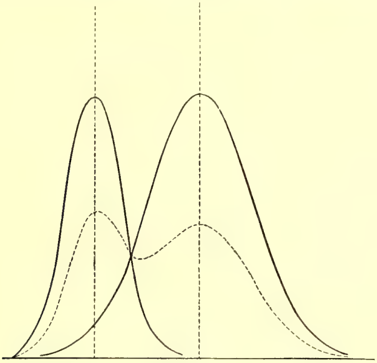

FIG. 2.

$$y = y_1 e^{-\frac{(x-b_1)^2}{2\sigma_1^2}} + y_2 e^{-\frac{(x-b_2)^2}{2\sigma_2^2}},$$

se
$$y = y_1 e^{-\frac{(x-b_1)^2}{2\sigma_1^2}}, \quad y = y_2 e^{-\frac{(x-b_2)^2}{2\sigma_2^2}}$$

sono le equazioni delle curve componenti.

Riescono evidenti, per questo modo di generazione, le seguenti proprietà delle curve dimorfiche:

---

* R. Livi "Sulla statura degli Italiani," Firenze, 1883. Vedi anche *Archivio per l' Antropologia e l' Etnologia*, Vol. 13, Firenze, 1883; e *Annali di Statistica*, Vol. 8, 1883, pp. 119—156.

Come le curve normali giacciono intieramente nel semipiano delle y positive e restan sempre a distanza finita dall' asse delle x. Inoltre devon rendersi anch' esse asintotiche a questo asse: perciò devono ammettere dei massimi le cui ascisse diremo *mode* †. Il modo di formazione ci dice che questi saranno al più due, come verificheremo rigorosamente in seguito.

Possiamo avere, cioè, la *unimodalità* (un solo massimo), o la *bimodalità* (due massimi separati da un minimo); queste due forme erano già state osservate dal Livi. Caso limite fra i due è quello osservato dal Weldon‡ in cui la curva presenta un solo massimo, ed un flesso (a destra od a sinistra) con tangente parallela all' asse delle x: allora può pensarsi che il minimo della curva bimodale sia venuto a coincidere con uno dei massimi.

La unimodalità o bimodalità dipende evidentemente dai parametri delle curve componenti: in questo scritto noi ci proponiamo la seguente ricerca:

Dati i parametri vedere se la curva dimorfica è unimodale o bimodale.

Il numero dei massimi dipende solo da alcune funzioni dei parametri delle componenti; infatti è questo un carattere invariantivo per spostamenti paralleli dell' asse delle y e per cambiamento delle scale delle x e delle y. Potremo perciò prendere $b_1 = 0$, ed allora b_2 che indicheremo con b' ci rappresenterà la distanza fra gli assi. Inoltre prendendo opportunamente la scala delle y potremo fare $y_1 = 1$ ed y_2' sarà il rapporto delle ordinate massime. Della scala delle x disporremo in seguito.

La equazione della curva dimorfica è allora:

$$y = e^{-\frac{x^2}{2\sigma_1^2}} + y_2' e^{-\frac{(x-b')^2}{2\sigma_2^2}},$$

in cui supponiamo $\sigma_2^2 \leqslant \sigma_1^2$.

Per studiare i massimi e minimi di questa funzione dovremo cercare i valori della variabile x che annullano la $\frac{dy}{dx}$; abbiamo così:

$$0 = -\frac{x}{\sigma_1^2} e^{-\frac{x^2}{2\sigma_1^2}} - y_2' \frac{(x-b')}{\sigma_2^2} e^{-\frac{(x-b')^2}{2\sigma_2^2}};$$

dividendo per $$\frac{e^{-\frac{x^2}{2\sigma_1^2}}}{\sigma_2^2}$$

---

† Per la quasi assoluta mancanza di scritti di Biometrica in lingua italiana, ho dovuto tradurre in italiano il nome di questo parametro dall' inglese *the mode*, introdotto dal Prof. K. Pearson dal francese *le mode*. Ho adottato la parola *moda*, anzichè *modo* o *modulo* per seguire i francesi, perchè mi è sembrata meglio corrispondente al significato del parametro. "Since this value may be said figuratively to be the most fashionable one, it has been called *the mode*." C. B. Davenport "The Statistical Study of Evolution" in *The Popular Science Monthly*, Sept. 1901.

‡ Citato dal Pearson, *Phil. Trans.* Vol. 185, A. pp. 95 *et seq.* Vedi anche C. B. Davenport *Statistical Methods with special reference to Biological Variation*, New York, 1899, p. 28, fig. 26.

si ha:
$$0 = x + y_2' \frac{\sigma_1^2}{\sigma_2^2}(x - b')\, e^{-\frac{x^2\left(1-\frac{\sigma_2^2}{\sigma_1^2}\right)}{2\sigma_2^2}+\frac{2xb'}{2\sigma_2^2}-\frac{b'^2}{2\sigma_2^2}}.$$

Poniamo:
$$y_2' \frac{\sigma_1^2}{\sigma_2^2} = k, \quad 1 - \frac{\sigma_2^2}{\sigma_1^2} = h, \quad b = \frac{b'}{\sigma_2\sqrt{2}},$$

inoltre cambiamo la scala delle x prendendo la nuova $x = \frac{x}{\sigma_2\sqrt{2}}$; la nostra equazione diviene allora:

$$(a) \quad 0 = x + k(x - b)\, e^{-(hx^2 - 2bx + b^2)} = f(x),$$

e di questa dobbiamo studiare le radici. In essa figurano tre parametri k, h, b che sono espressi in funzione dei parametri delle curve componenti dalle relazioni:

$$k = \frac{y_2}{y_1}\frac{\sigma_1^2}{\sigma_2^2}, \quad h = 1 - \frac{\sigma_2^2}{\sigma_1^2}, \quad b = \frac{b_2 - b_1}{\sigma_2\sqrt{2}},$$

e supponendo $\sigma_2 \leqslant \sigma_1$, $b_2 \geqslant b_1$ (il chè non toglie generalità alla ricerca perchè se fosse $b_2 < b_1$ potremmo invertire il senso dell' asse delle x), i parametri k, h, b devon sempre soddisfare alle diseguaglianze:

$$k > 0, \quad 0 \leqslant h < 1, \quad b \geqslant 0.$$

2. *Criterio per giudicare del numero dei massimi delle curve dimorfiche.*

Noi studieremo adesso le radici della $f(x) = 0$ per risolvere la questione prima enunciata:

Dati i parametri delle curve componenti, e perciò k, h, b, vedere quanti massimi ha la curva dimorfica. Dovremo perciò cercare quando la equazione (a) ammette una sola radice reale e quando ne ammette 3.

Nel caso particolare $b = 0$ (ovvero $b_1 = b_2$), cioè curve componenti con assi coincidenti, la $f(x) = 0$ si spezza nelle due $x = 0$, ed $1 + ke^{-hx^2} = 0$ che non ammette radici reali perchè k e l' esponenziale sono sempre positivi; onde in questo caso esiste un solo massimo, per $x = 0$, corrispondente al massimo comune delle curve componenti, e ciò era evidente.

L' altro caso particolare $h = 0$, onde $\sigma_1 = \sigma_2$, lo considereremo a parte. Nel caso generale in cui
$$k > 0, \quad 0 < h < 1, \quad b > 0$$
ci ricondurremo allo studio delle radici di una equazione algebrica di terzo grado.

In generale la (a) può scriversi:

$$0 = \frac{x}{k(x - b)} + e^{-(hx^2 - 2bx + b^2)}.$$

Ponendo:

$$(b) \quad z_1 = e^{-(hx^2 - 2bx + b^2)},$$

$$(c) \quad z_2 = \frac{x}{k(b-x)},$$

per le radici della (a) avremo $z_1 = z_2$.

Studiamo le due curve (b) e (c); se le riferiamo agli stessi assi, le ascisse delle loro intersezioni ci daranno le radici della (a).

Studio di (b).

$$z_1 = e^{-(hx^2 - 2bx + b^2)}.$$

Essa è una curva *normale*. Infatti la sua equazione può scriversi:

$$z_1 = e^{b^2\left(\frac{1-h}{h}\right)} e^{-\frac{\left(x-\frac{b}{h}\right)^2}{\frac{1}{h}}}.$$

La moda è $\frac{b}{h}$, la deviazione normale $\frac{1}{\sqrt{2h}}$, l'ordinata massima $e^{b^2\frac{1-h}{h}}$.

Le sue proprietà sono ben note, e perciò è inutile insistervi.

Studio di (c).

$$z_2 = \frac{x}{k(b-x)}.$$

Può scriversi

$$kz_2x - kbz_2 + x = 0.$$

È una *iperbole equilatera* che passa per l'origine; asintoti sono le rette

$$x = b, \quad z_2 = -\frac{1}{k}.$$

Per $x < 0$ o per $x > b$, z_2 è negativo; onde per studiare le intersezioni colla (b) che ha l'ordinata sempre positiva, basta considerare il ramo per $0 < x < b$; in esso la z_2 cresce con continuità da 0 ad ∞ $\left(\text{la } \frac{dz_2}{dx} = \frac{b}{k(b-x)^2} \text{ è sempre positiva}\right)$.

Da queste prime osservazioni possiam dedurre che le radici della (a), di cui una almeno è sempre reale, sono comprese nell' intervallo $(0, b)$. In questo intervallo tanto la (b) che la (c) son sempre crescenti, positive. (Infatti il massimo della (b) è per $x = \frac{b}{h} > b$). Vedi fig. 3.

Per continuare il nostro studio formiamo la derivata della $f(x)$: essa è

$$\frac{df(x)}{dx} = 1 + k\{1 - (x-b)(2hx - 2b)\} e^{-(hx^2 - 2bx + b^2)},$$

uguagliandola a zero:

$$\frac{1}{k(2hx^2 - 2b(1+h)x + 2b^2 - 1)} = e^{-(hx^2 - 2bx + b^2)}.$$

Ponendo:

$$(b) \quad z_1 = e^{-(hx^2-2bx+b^2)},$$

$$(d) \quad z_3 = \frac{1}{k\{2hx^2 - 2b(1+h)x + 2b^2 - 1\}},$$

alle radici della $\frac{df(x)}{dx} = 0$ corrispondono le ascisse delle intersezioni delle due curve (*b*) e (*d*) quando siano inferite agli stessi assi.

La (*b*) è già stata veduta.

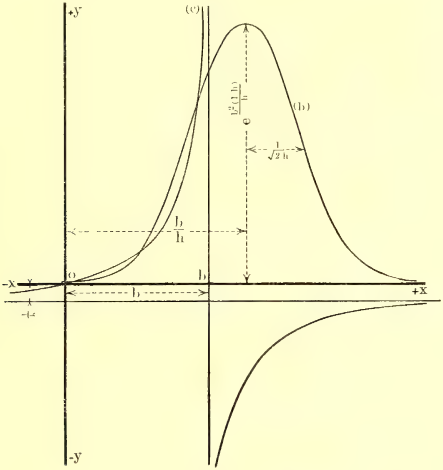

FIG. 3.

Studio di (*d*).

$$z_3 = \frac{1}{k\{2hx^2 - 2b(1+h)x + 2b^2 - 1\}}.$$

Per x finito z_3 non si annulla mai, però l' asse delle x è un asintoto della curva. Perchè z_3 cambi segno deve passare per il valore ∞ e ciò avviene in corrispondenza alle radici della:

$$2hx^2 - 2b(h+1)x + 2b^2 - 1 = 0,$$

che sono
$$\left.\begin{matrix} x_1 \\ x_2 \end{matrix}\right\} = \frac{b(h+1) \mp \sqrt{b^2(h^2+2h+1) - 2h(2b^2-1)}}{2h}.$$

ovvero:
$$\left.\begin{matrix} x_1 \\ x_2 \end{matrix}\right\} = \frac{b(h+1) \mp \sqrt{b^2(1-h)^2 + 2h}}{2h}.$$

Ora se $1-2b^2$ è negativo, le due radici sono entrambe positive, se $1-2b^2$ è positivo, è positiva solo la x_2. Io dico che in ogni caso x_2 è maggiore di b; infatti si ha:

$$x_2 = \frac{b(h+1)+\sqrt{b^2(1-h)^2+2h}}{2h} > \frac{b(h+1)+b(1-h)}{2h} = \frac{b}{h} > b.$$

Riguardo ad x_1, è positivo solo se $2b^2>1$, $b>\frac{1}{\sqrt{2}}$; in questo caso è minore di

$$\frac{b(h+1)}{2h}.$$

In ogni caso z_3 è positivo per $x<x_1$, negativo per $x_1<x<x_2$, positivo di nuovo per $x>x_2$. Poichè a noi la curva interessa solo nel tratto $0<x<b$, segue che per $b<\frac{1}{\sqrt{2}}$, nel nostro tratto z_3 è sempre negativo, mentre è almeno in parte positivo se $b>\frac{1}{\sqrt{2}}$. È facile vedere che in questo intervallo è sempre crescente, infatti la derivata è positiva.

Inoltre per $x=0$, $$z_3 = \frac{1}{k(2b^2-1)}.$$

La curva è tracciata in figura. (Vedi fig. 4.)

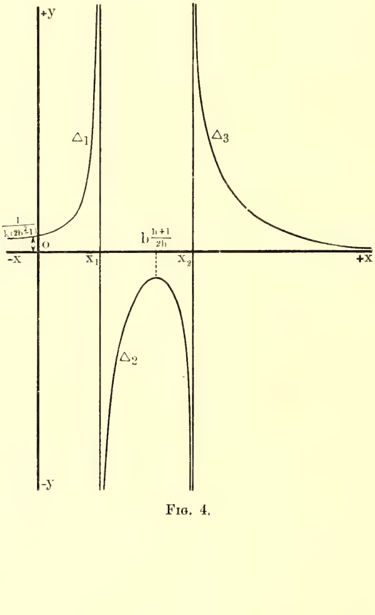

FIG. 4.

A noi interessa solo il ramo indicato colla lettera Δ_1 che partendo dal punto $\left(x=0,\ z_3=\frac{1}{k(2b^2-1)}\right)$ cresce fino a divenire asintotico alla retta $x=x_1$. Consideriamo ora le intersezioni delle due curve (*c*) e (*d*) nell' intervallo $0<x<b$; le loro ascisse sono le radici della equazione di terzo grado:

$$\frac{x}{b-x}=\frac{1}{\{2hx^2-2b(h+1)x+2b^2-1\}},$$

cioè, in generale,

$$2hx^3-2b(h+1)x^2+2b^2x-b=0.$$

La indicheremo con $R(x)=0$. Si ha:

$$R(-\infty)<0,$$
$$R(0)=-b,$$
$$R(b)=-b,$$
$$R(+\infty)>0.$$

Perciò la $R(x)=0$ ammette certo una radice reale, positiva, maggiore di b, e nell' intervallo $(0,\ b)$ o due o nessuna.

Ciò posto supponiamo che la $f(x)=0$ ammetta tre radici reali e distinte x', x'', x''', con $x'<x''<x'''$. Ad esse corrisponderanno 3 intersezioni delle curve (*b*) e (*c*), indicate nella fig. 5 colle lettere *A*, *B*, *C*. Per ciò che abbiamo visto studiando queste curve sarà anche

$$0<x'<x''<x'''<b.$$

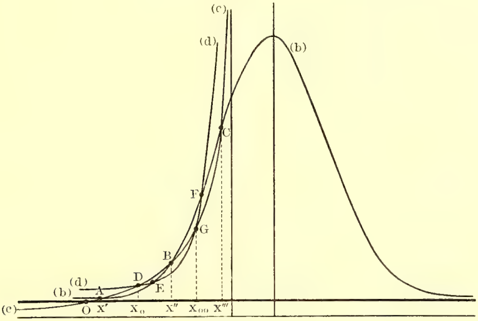

Fig. 5.

Poichè la $f(x)$ si annulla in x' ed x'', per la continuità, la $\frac{df(x)}{dx}=0$ fra x' ed x'' deve ammettere una radice (od un numero dispari di radici); così fra x'' ed x'''. Perciò la (*d*) deve tagliare la curva normale (*b*) in almeno un punto *E* compreso fra *A* e *B*, ed in *F* fra *B* e *C*.

Io dico che la (d), nell' intervallo $x=0$, $x=b$, taglierà la (c) in due punti D, G compresi rispettivamente fra A e B, B e C, ed in essi soltanto.

Infatti in più di due punti non può tagliarla perchè se no l' equazione $R(x)=0$, che si ha considerando le intersezioni delle (c) e (d), avrebbe più di due radici reali fra 0 e b contro ciò che abbiam visto; inoltre la (c) essendo continua, monodroma, continuamente crescente, deve tagliare il contorno chiuso $AEBD$ in un numero pari di punti: ma essa taglia in un punto, od in un numero dispari di punti il lato AEB, onde dovrà tagliare in un punto D anche l' altro lato ADB.

Nello stesso modo si dimostra la seconda intersezione in G. Siano x_0, x_{00} le ascisse corrispondenti a queste due intersezioni: saranno le radici di $R(x)=0$ comprese fra 0 e b. Segue che:

Condizione necessaria perchè la curva sia bimodale è che la $R(x)=0$ abbia due radici reali x_0, x_{00}, fra 0 e b, e che per esse la successione dei segni di $f(0)$, $f(x_0)$, $f(x_{00})$ abbia due variazioni. La seconda parte è giustificata dal fatto che

$$x' < x_0 < x'', \quad x'' < x_{00} < x''',$$

perchè nell' intervallo $(0, b)$ le tre curve (b), (c), (d) son sempre crescenti: così in ciascuno degli intervalli $(0, x_0)$, (x_0, x_{00}) cade una sola radice di $f(x)=0$. Notiamo che $f(0)=-kbe^{-b^2}$ è sempre negativo.

Questa condizione è anche sufficiente; infatti se essa è soddisfatta, $f(x)$, per la continuità, ammette una radice fra 0 ed x_0, una seconda fra x_0 ed x_{00}, una terza fra x_{00} e b, poichè allora l' unica possibile successione di segni è:

$$\begin{array}{cccc} f(0), & f(x_0), & f(x_{00}), & f(b)=b. \\ - & + & - & + \end{array}$$

Questo procedimento mostra anche che le curve dimorfiche non possono avere più di due massimi, poichè la $R(x)=0$ non può ammettere più di due radici reali fra 0 e b.

Il caso limite fra la unimodalità e la bimodalità, cioè la curva con un flesso con tangente orizzontale si ha quando $f(x_0)=0$ ovvero $f(x_{00})=0$.

Infatti allora deve aversi per lo stesso valore di x, corrispondente a due delle radici x', x'', x''' che vengono a coincidere:

$$f(x)=0, \quad \frac{df(x)}{dx}=0,$$

cioè nel punto corrispondente a questa ascissa la (b) deve tagliare tanto la (c) che la (d), perciò questo x dev' esser radice di $R(x)=0$: uno dei due numeri x_0, x_{00}.

Si hanno due condizioni per il caso limite ($f(x_0)=0$ ovvero $f(x_{00})=0$) perchè nella curva dimorfica il flesso con tangente orizzontale può trovarsi a destra (Vedi fig. 6) od a sinistra del massimo, e nella figura 5 perchè posson venire a coincidere i punti A e B, od i B e C.

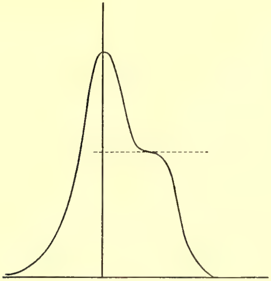

FIG. 6.

Riepilogando, il procedimento per vedere se la curva dimorfica, di cui son dati i 6 parametri y_1, y_2, b_1, b_2, σ_1, σ_2, ha uno o due massimi è il seguente:

(1) Si costruiscono le funzioni dei parametri k, h, b.

(2) Si cercano le radici reali di

$$R(x) = 2hx^3 - 2b(h+1)x^2 + 2b^2x - b = 0$$

(che può anche scriversi $2x(x-b)(hx-b) - b = 0$)

comprese fra 0 e b. Se non ne esistono o ve n' è una doppia la curva è
.........*unimodale.*

Se ci sono due radici reali e distinte x_0, x_{00}:

(3) Si sostituiscono in $f(x)$. Possono allora darsi i seguenti casi

o $f(x_0) = 0$ o $f(x_{00}) = 0$ e si ha il *caso limite,*
o $f(x_0) < 0$ e la curva è *unimodale,*
o $f(x_0) > 0$, e in tal caso se $f(x_{00}) > 0$ curva *unimodale,*
se $f(x_{00}) < 0$ curva *bimodale.*

Così la ricerca è completamente risoluta nel caso generale.

Riguardo al valore delle mode x', x''' nel caso della bimodalità si attengono per approssimazione come radici della $f(x) = 0$: esse sono già separate poichè

$$0 < x' < x_0 \quad \text{e} \quad x_{00} < x''' < b.$$

Si ricordi che si è effettuata la trasformazione $x = \dfrac{x}{\sigma_2\sqrt{2}}$.

3. *Condizioni sufficienti per la unimodalità.*

Un caso in cui si può asserire subito la unimodalità è quello in cui $b < \dfrac{1}{\sqrt{2}}$; allora abbiamo visto che la (d) giace per $0 < x < b$ dalla parte delle ordinate negative, perciò non può incontrare la (c) che in quell' intervallo è sempre dalla parte positiva, e la $R(x)=0$ che dà le ascisse delle intersezioni delle (c) e (d), non ha tra 0 e b radici reali.

Onde ricordando le posizioni fatte:

Condizione sufficiente per la unimodalità è:

$$b_2 - b_1 < \sigma_2.$$

Cioè: La curva dimorfica è unimodale se la distanza tra gli assi delle componenti è minore della più piccola delle deviazioni normali.

Ricordiamo che la deviazione normale è geometricamente la distanza dei flessi dall' asse.

Io dico che la curva è certo unimodale anche se la distanza tra gli assi è minore del doppio di questa quantità.

Per stabilire questo risultato bisogna studiare la equazione $R(x)=0$ che può scriversi sotto le due forme identiche:

$$2hx^3 - 2b\,(h+1)\,x^2 + 2b^2x - b = 0,$$

$$2x\,(x-b)\,(hx-b) - b = 0.$$

Osserviamo la curva $y = R(x)$: essa incontra la retta $y = -b$ nei punti

$$x_1 = 0, \quad x_2 = b, \quad x_3 = \frac{b}{h}.$$

e poichè $0 < h < 1$ si ha $x_1 < x_2 < x_3$. A noi interessano le radici comprese fra 0 e b e perciò solo in questo tratto vogliamo studiare la $y = R(x)$, così non teniamo conto di x_3.

Considerando la derivata

$$\frac{dR(x)}{dx} = 6hx^2 - 4b\,(h+1)\,x + 2b^2 = 2S\,(x),$$

si vede che i punti di massimo o minimo x_0', x_0'', sono compresi negli intervalli $(0, b)$; $(b, +\infty)$ come ci indica la successione dei segni di $S(0) = +b^2$, $S(b) < 0$, $S(+\infty) = +\infty$.

Onde nell' intervallo $(0, b)$ c' è un solo punto x_0', di massimo (infatti ivi la $\dfrac{d^2R(x)}{dx^2} = 4\,\{3hx - b\,(h+1)\}$ è negativa). La figura 7 mostra l' andamento della curva in questo tratto.

Il discriminante di $R(x)=0$ è $R(x_0')$, poichè secondo che

$$R(x_0') \begin{matrix} < \\ = \\ > \end{matrix} 0 \; \left.\begin{matrix} \text{non esistono radici reali} \\ \text{esiste una radice doppia} \\ \text{esistono due radici reali e distinte} \end{matrix}\right\}$$

di $R(x)=0$ comprese fra 0 e b.

Il valore di x_0' è

$$x_0' = \frac{b\,\{h+1-\sqrt{(h+1)^2-3h}\}}{3h}.$$

Sostituendo e sviluppando si trova che le diseguaglianze $R(x_0') \lesseqgtr 0$ equivalgono alle

$$\frac{\{9h(h+1)-2(h+1)^3\}+2\{(1+h)^2-3h\}^{\frac{3}{2}}}{27h^2} \lesseqgtr \frac{1}{2b^2}.$$

Vogliamo ora vedere il massimo valore di b indipendente da h e da k per il quale si può asserire la unimodalità della curva.

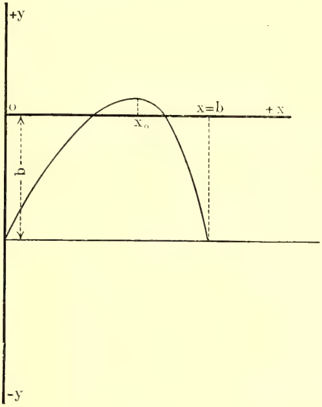

FIG. 7.

Perciò scriviamo la condizione sotto la forma:

$$\{(h+1)^2-3h\}^3 < \{(h+1)^3+h(\gamma h-\tfrac{9}{2})\}^2,$$

dove
$$\gamma = \frac{27}{4b^2}-\frac{9}{2}.$$

Sviluppando si trova:

$$\gamma^2h^2+\gamma(2h^3+6h^2-3h+2)+9h^3+\tfrac{9}{4}>0.$$

Cerchiamo il minimo valore di γ per cui questa è soddisfatta qualunque sia h fra 0 ed 1.

Prendendo h molto piccolo si ha:

$$2\gamma+\tfrac{9}{4}>0, \quad \gamma>-\tfrac{9}{8}.$$

Anche per il valore $\gamma=-\frac{9}{8}$ la diseguaglianza è realmente soddisfatta; infatti sostituendo e riducendo si ha

$$h^2-\tfrac{13}{16}h+\tfrac{1}{2}>0,$$

che è verificata per $h = 0$, per $h = 1$ ed anche per $h = \frac{13}{32}$ per cui il primo membro assume il minimo valore: $\frac{1}{2}\{1 - \frac{1}{2}(\frac{13}{16})^2\} > 0$.

Ricordando la posizione $\gamma = \frac{9}{2}\left(\frac{3}{2b^2} - 1\right)$, la condizione $\gamma > -\frac{9}{8}$ equivale a $b^2 < 2$.

Perciò la curva è certo unimodale se

$$b_2 - b_1 < 2\sigma_2:$$

Come avevamo prima affermato.

Potrebbero trovarsi altre condizioni per la unimodalità pensando b non costante, caso completamente trattato, ma funzione di h. Con ciò si verrebbero a stabilire delle relazioni fra $b_2 - b_1$, σ_2 e σ_1. Però non si ottengono così condizioni notevolmente più estese di quelle già poste.

Si potrebbe trovare in modo analogo un numero b_0 tale che per $b > b_0$ il discriminante sia positivo qualunque sia h, però *non si possono stabilire delle condizioni sufficienti per la bimodalità indipendenti da k.* Infatti sappiamo che condizione necessaria per la bimodalità è che $f(x_0)$ ed $f(x_{00})$ siano il primo positivo, il secondo negativo. Possiamo scrivere:

$$f(x_0) = A_1 - kB_1, \qquad f(x_{00}) = A_2 - kB_2,$$

dove $A_1 B_1$, $A_2 B_2$ sono quantità positive. Se esse sono indipendenti da k, io posso sempre imaginare k così piccolo o così grande che siano $f(x_0)$ ed $f(x_{00})$ entrambi positivi o negativi. Perciò non posson trovarsi valori di b costanti, o funzioni di h indipendenti da k, per i quali la curva dimorfica sia necessariamente bimodale.

4. *Caso particolare: curve componenti di ugual deviazione normale: $h = 0$.*

In questo caso uguagliando a zero la derivata si ha:

$$x + k(x - b)\, e^{2bx - b^2} = 0.$$

Poniamo $2bx - b^2 = z$ da cui $x = \dfrac{z + b^2}{2b}$ e $x - b = \dfrac{z - b^2}{2b}$.

L' equazione diviene:

$$z + b^2 + k(z - b^2)\, e^z = 0 = F(z).$$

Dobbiam vedere quando questa ammette uno e quando tre radici reali: a queste corrispondono in generale le ascisse delle intersezioni delle due curve:

$$z_1 = -\frac{z + b^2}{z - b^2}, \qquad z_2 = ke^z.$$

La
$$\frac{dF(z)}{dz} = 0 = 1 + k\{z - b^2 + 1\}\, e^z$$

ha per radici le ascisse delle intersezioni delle curve:

$$z_3 = -\frac{1}{z - b^2 + 1}, \qquad z_2 = ke^z.$$

Una di queste, la z_2, è sempre crescente, sempre positiva: Per z crescente da $-\infty$ a 0, z_2 cresce da 0 a k, per z crescente da 0 a $+\infty$ la z_2 varia da k ad ∞.

Le altre due curve sono iperbole equilatere.

Per la prima si ha che per

$$z > b^2, \quad z_1 < 0,$$
$$-b^2 < z < b^2, \quad z_1 > 0,$$
$$z < -b^2, \quad z_1 < 0;$$

per la seconda per

$$z > b^2 - 1, \quad z_3 < 0,$$
$$z < b^2 - 1, \quad z_3 > 0.$$

Le intersezioni della z_1 colla z_2 sono comprese nella striscia limitata dalle rette $z = -b^2$ e $z = +b^2$.

Quelle delle z_3 colla z_2 nell' intervallo $z = -\infty$ e $z = -(1 - b^2)$. Supponiamo che la $F(z) = 0$ ammetta tre radici reali e distinte: allora fra due intersezioni della z_1 colla z_2, deve esserci una intersezione della z_3 colla z_2. (Vedi fig. 8.)

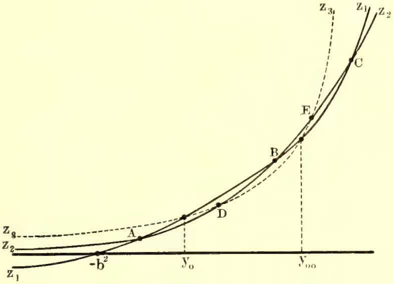

FIG. 8.

Siccome son tutte curve omali crescenti, le intersezioni delle z_1 e z_2 devon comprendere quelle delle z_1 e z_3. Le ascisse di queste siano y_0, y_{00}. Esse sono le radici della:

$$(z + b^2)(z - b^2) + (z + b^2) = z - b^2,$$

ovvero

$$z^2 - b^4 + 2b^2 = 0 \text{ onde } y_0 = -b\sqrt{b^2 - 2},$$
$$y_{00} = +b\sqrt{b^2 - 2}.$$

Inoltre le $F(-b^2)$, $F(y_0)$, $F(y_{00})$, $F(b^2)$ devon presentare segni alternati.

Ora $$F(-b^2) < 0 \text{ e } F(+b^2) > 0,$$

perciò devon essere $F(y_0)$ positivo ed $F(y_{00})$ negativo.

Evidentemente queste condizioni sono anche sufficienti perchè la $F(z) = 0$ ammetta tre radici reali e distinte.

Segue che: *Condizioni necessarie ed insieme sufficienti perchè la curva dimorfica risultante di componenti normali di ugual deviazione normale sia bimodale sono:*

$$(1) \quad y_0 \text{ ed } y_{00} \text{ reali onde } b > \sqrt{2},$$

$$(2) \quad \{b - \sqrt{b^2 - 2}\} - k\,\{b + \sqrt{b^2 - 2}\}\, e^{-b\sqrt{b^2-2}} > 0$$

e

$$\{b + \sqrt{b^2 - 2}\} - k\,\{b - \sqrt{b^2 - 2}\}\, e^{b\sqrt{b^2-2}} < 0.$$

Intanto *possiamo asserire la unimodalità se* $b < \sqrt{2}$, ovvero $b_2 - b_1 < 2\sigma$.

Se $b_2 - b_1 > 2\sigma$, allora dovremo vedere se sono soddisfatte entrambe le diseguaglianze prima scritte.

Nel caso che lo siano si ha la bimodalità; se anche una sola non è verificata la curva è unimodale.

Si ha il caso limite quando è soddisfatta una delle due relazioni:

$$\{b - \sqrt{b^2 - 2}\} - k\,\{b + \sqrt{b^2 - 2}\}\, e^{-b\sqrt{b^2-2}} = 0,$$

$$\{b + \sqrt{b^2 - 2}\} - k\,\{b - \sqrt{b^2 - 2}\}\, e^{b\sqrt{b^2-2}} = 0.$$

MISCELLANEA.

I. On some Dangers of Extrapolation.

By EMILY PERRIN, University College, London.

(1) It is well known that most excellent graduation results both in the case of physical and vital investigations may be obtained by fitting algebraic or trigonometrical curves to a limited range of observation. Such curves are in constant use for interpolation, not only in physics and demography, but also in chemistry, in actuarial science, and in empirical investigations in all branches of technical research. So long as such curves or algebraic formulae are applied for the purposes of interpolation within the range of observation, their use is not only justifiable, but indeed indispensable. This statement of course supposes that a good formula has been selected and has been properly fitted to the observations.

When we examine, however, the excellence of fit of even an arbitrarily chosen curve to a given range of data, when we see how it smooths the irregularities, and provides well within the limits of probable error the graduation that the chemist or engineer or actuary is eagerly seeking, we are tempted to continue our empirical representation of the data beyond the range of actual observation and predict the future from the past, or the condition of the unobserved from the observed. This extrapolation is one of the most fascinating fields of enquiry and yet one in which definite conclusions are most difficult to reach and pitfalls frequent and dangerous. How often is this extrapolation indulged in almost unconsciously by the scientific enquirer! We know now that the proportionality of stress and strain is only true within narrow limits, yet the early investigators extrapolated from this linearity all across the mysteries of set, yield-point, and stricture, up to rupture! Within quite recent years we have, we fancy, seen distinguished physicists and chemists running along tangents as if every observation-curve beyond the observed range ended in an indefinitely extended point of inflexion. Yet their want of logic is only comparable with that of the early physicists who extended Hooke's Law or Boyle's Law beyond the limits of observation, or of the later physicists who apply the deductions from Hooke's Law to the stress and strain of the solid earth, or relations between physical attributes at known temperatures and pressures to what may be supposed to happen beyond the range at which it has hitherto been possible to experiment.

The present enquiry is, of course, of a much humbler nature, but it may serve possibly as a warning on the dangers of extrapolation. Even if it does not deal with such important problems as the physics of the solid earth, it does deal with things which have been subjected to a like treatment. A parabola of a sufficiently high order—such a curve as has hitherto been often used by physicists and chemists—has been selected to describe the observed range of measurements, and then extrapolation has been attempted at a very small distance outside that range and the results compared with actual observation. When the conclusion to be drawn is merely a note of warning, may we not learn from the lesser as to the greater? It seems to us that such "extrapolation" at least is justifiable.

(2) The data dealt with are drawn from the demographic statistics of the City of Buénos-Ayres and are published in the *Annuaire Statistique de la Ville de Buénos-Ayres* of which twelve volumes have now appeared. This publication is to some extent a model for municipal statistical work, and we have to cordially thank M. Albert B. Martinez the *Directeur de la Statistique municipale* of Buénos-Ayres for our copy of this interesting book. Buénos-Ayres is a town which is altering demographically in two very sensible ways; there is a rapidly increasing population, together with improving sanitary and medical conditions, indicated by a falling death-rate and a decrease in the percentage of still-born children. The data in our possession started from the year 1887, but to allow of extrapolation beyond the start of the range we did not use that year. The following thirteen years' returns were then available for investigation at the time of the inquiry:

TABLE I.

City of Buénos-Ayres.

Year	Population on Dec. 31	Deaths per 1000	Still-born per 1000
1888	455,167	27·17	2·45
1889	523,452	28·15	2·49
1890	547,144	30·00	2·36
1891	535,060	24·32	2·46
1892	554,713	24·05	2·29
1893	580,371	22·40	2·22
1894	603,012	22·72	2·06
1895	677,780	22·05	1·73
1896	712,095	19·16	1·78
1897	738,484	19·25	1·78
1898	765,744	17·67	1·70
1899	795,323	17·06	1·63
1900	821,293	20·09*	1·68

* Small-pox epidemic.

The problem was then this: Graduate these results by a sufficiently high parabola, and predict by extrapolation the demographic condition of the town before and after the period covered by the above data.

The method of solution adopted was as follows: The successive moments of the observations about the middle point of the range were calculated by the processes indicated in *Biometrika*, Vol. II. pp. 15 *et seq.*, and the series of best fitting parabolas was determined. We halted when a thoroughly good fit had been found. Thus we stopped at the fifth order parabola in the case of population and at the fourth in the case of the death and still-born rates. Judged by any test of goodness of fit it will be found that *within the range dealt with* our curves give excellent graduation. For example, the mean error made in fitting the population with a straight line is 16·2 thousands, while the mean error made in using a curve of the fifth order is less than half this, being 6·5 thousands. This connotes a mean error in the population as estimated by interpolation of almost exactly one per cent., which may be considered for all purposes of interpolation in vital statistics as very satisfactory.

If we take the death-rate statistics we do not get anything like the same improvement if we pass from a straight line to a parabola of the fourth order. In fact the mean error made in the death-rate by the latter curve is 1·07, while it is only 1·18 if we use the best fitting straight line, or the fourth order parabola makes an error of 4·7 per cent. on an average in the death-rate, the straight line an error of 5·7 per cent. This is a sensible but not a considerable improvement, and it did not seem that a substantially greater gain would be made by continuing the process further. Clearly, when we consider the effect of epidemic sicknesses, we can hardly hope to get a closer result from a graduating curve.

Lastly, turning to the still-born rate, we have for the parabola of the fourth order a mean error of ·051 and for the straight line a mean error of ·075, corresponding to 2·5 and 3·7 percentage errors respectively. This is a sensible betterment, but nothing like as good as in the case of the population data. We may say that by using a high parabola instead of a straight line we better the fit two-and-a-half times for the population, one-and-a-half times for the still-born, and one-and-a-quarter times for the death-rate. In the last two cases therefore straight lines would give quite reasonable graduation or interpolation formulae.

The actual equations to the curves, the year 1894 being in each case taken as origin of x, the unit of which is a year, are:

Population. Straight line:

$$y = 639{\cdot}1667 + 29{\cdot}8186x.$$

Fifth order parabola:

$$y = 617{\cdot}729 + 44{\cdot}8543x + 3{\cdot}599{,}110x^2 - 1{\cdot}555{,}483x^3 - {\cdot}083{,}917x^4 + {\cdot}033{,}424x^5.$$

The unit of y is here 1000 individuals.

Death-rate per 1000. Straight line:

$$y = 22{\cdot}5383 - 1{\cdot}0428x.$$

Fourth order parabola:

$$y = 21{\cdot}9981 - 1{\cdot}345{,}685x + {\cdot}052{,}220x^2 + {\cdot}014{,}016x^3 - {\cdot}000{,}330x^4.$$

The unit of y is one in the thousand.

Still-born per 1000. Straight line:

$$y = 2{\cdot}0471 - {\cdot}08799x.$$

Fourth order parabola:

$$y = 2{\cdot}0173 - {\cdot}130{,}823x + {\cdot}005{,}316x^2 + {\cdot}001{,}983x^3 - {\cdot}000{,}131x^4.$$

The unit of y is one in the thousand.

The results obtained by observation and from calculation by the parabolas between the years 1888 and 1900 are given in the accompanying Table II. This table shows at once that the results are quite satisfactory within the range of observation. The same point is brought out graphically from the diagram. Confining our attention to the curves between the verticals Y_1Y_1 and Y_2Y_2, we could hardly hope to better the graduation provided.

TABLE II.

Interpolation Calculations.

Year	Population in 1000's		Death-Rate per 1000		Still-born Rate per 1000	
	Calculated	Difference	Calculated	Difference	Calculated	Difference
1888	446	− 9	28·50	+1·33	2·40	−·05
1889	521	− 2	28·08	− ·07	2·47	−·02
1890	540	− 7	27·24	−2·76	2·47	+·11
1891	543	+ 8	26·10	+1·78	2·39	−·07
1892	552	− 3	24·78	+ ·73	2·28	−·01
1893	578	− 2	23·38	+ ·98	2·15	−·07
1894	618	+15	22·00	− ·72	2·02	−·04
1895	665	−13	20·72	−1·28	1·89	+·16
1896	709	− 3	19·62	+ ·46	1·79	+·01
1897	744	+ 6	18·78	− ·47	1·72	−·06
1898	768	+ 2	18·26	+ ·59	1·67	−·03
1899	790	− 5	18·12	+1·06	1·66	+·03
1900	831	+10	18·40	−1·69	1·68	·00

But now let us look at the problem of extrapolation. Can we prophesy what happened in 1887, the year before our range of observation starts, or in the years 1901 and 1902, the data of which have been received since our curves were determined? Table III. gives the actually observed and the predicted results, (i) on the basis of a straight line extrapolation, (ii) on the basis of a high parabolic extrapolation.

TABLE III.

Extrapolation Calculations.

Year	Population in 1000's					Death-Rate per 1000					Still-born Rate per 1000				
	Parabola		Line		Actual	Parabola		Line		Actual	Parabola		Line		Actual
		Δ		Δ			Δ		Δ			Δ		Δ	
1887	251	−187	430	−·08	438	28·38	+ ·79	29·84	+2·25	27·59	2·20	+·36	2·66	+·82	1·84
1901	935	+ 87	848	·00	848	19·15	+ ·55	15·24	−3·36	18·60	1·73	+·09	1·43	−·21	1·64
1902	1162	+284	878	+·08	870	20·39	+4·19	14·20	−2·00	16·20	1·79	+·11	1·34	−·34	1·68
Mean Δ Extrapolation	—	186	—	·05	—	—	1·84	—	2·54	—	—	·19	—	·46	—
Mean Δ Interpolation	—	6·5	—	16·2	—	—	1·07	—	1·18	—	—	·05	—	·08	—

Now these results show that for the death-rate and the still-born rate the parabolas give better results for extrapolation than the straight lines, but that both representations have a mean error much in excess of the average mean error of interpolation within the range on which the calculation is based. An examination of the diagram shows that both rate curves are actually inadmissible a little beyond the range, for we see that either calculated rate tends to *fall* beyond the beginning of the range and *rise* after the end of it; there can hardly be a doubt that the very reverse of this must represent the actual state of affairs. In the case of the population curves this divergence from the facts does not occur; the total population falls before the beginning of the range and rises after the end of it as we should anticipate. But we see that the great closeness of the calculated to the observed population *within* the range has been gained by immensely emphasising the fall before and the rise after the range, so that the curve becomes worthless for purposes of extrapolation. Indeed while the parabola within the range is two to three times as good as the best representative line, the latter is indefinitely better than the former for extrapolation, giving indeed extremely good results. We are thus forced to the conclusions that:

(i) Empirical formulae which fit extremely well within the range of observation may give very bad extrapolation results only just outside that range.

(ii) Of two curves that which gives by far the better interpolation results, may give by far the worse extrapolation results. We cannot argue from excellency of fit within a given range to a fitness for prophesying what occurs even just outside that range.

Generally we believe that while empirical formulae—including in that term even general laws like Hooke's or Boyle's—may be excellent for interpolation within the range of actual observation, they cannot be used in either physics or vital statistics without extreme caution, if indeed they can be used at all, to predict what will occur even just outside that range. While interpolation and graduation can be satisfactorily carried out by the use of a variety of empirical curves, there is no corresponding method of extrapolation unless we have some solid reasons for assuming that the phenomena can only be represented by a formula or curve of a very definite type.

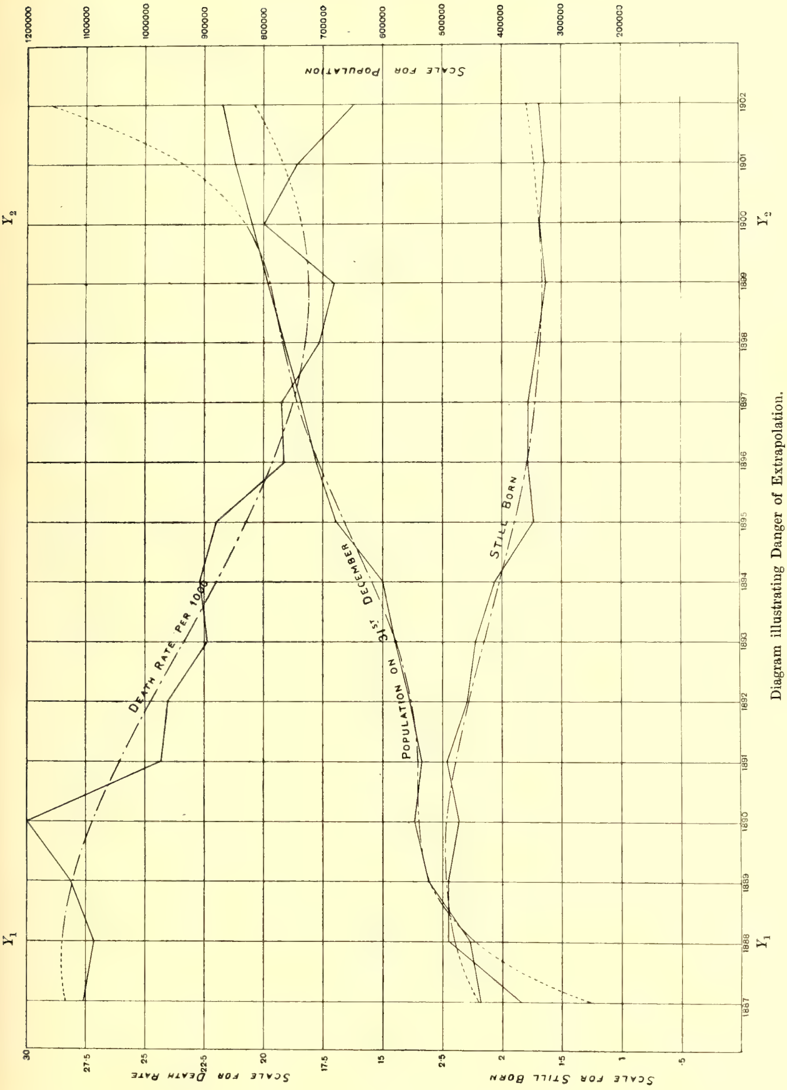

Diagram illustrating Danger of Extrapolation.

II. On Differentiation and Homotyposis in the Leaves of *Fagus sylvatica*.

BY KARL PEARSON, F.R.S., with the assistance of MARION RADFORD.

(i) If an examination be made of a beech tree there will be found to be a distinction between the nature of the growth at the free higher parts of the tree and at the lower more accessible portions. Botanists have distinguished these two types as 'sun' and 'shade' branches. How far these differences of growth are entirely due to differences merely of light or even of air environment may be legitimately doubted. The free south side of a large beech tree does not as a rule abound in sun branches, while the north side exhibits only shade branches. There appears to be not only some factor beyond the light and air environment controlling the development of the tree, but the age of the tree and the age of the part of the tree considered seem also influential. Sun branches at any rate occur where the growth of the tree is most rapid, and shade branches where it is less rapid. Our experience is that with old and large beech trees, even if they are growing freely on a common, the sun branch is confined to the upper portions of the tree, and a random collection of sprays will result in shade branches only. The accompanying photographic reproductions which I owe to the kindness of Professors F. W. Oliver and A. G. Tansley will illustrate the difference between the two kinds of growth. We have collected a considerable number of sprays from beech trees this autumn and examined a considerable number collected by other persons, and it is safe to assert that a random gathering round the accessible parts of a large beech tree will result in a collection consisting in great bulk or more probably entirely of 'shade' branches.

(ii) If a spray representing a year's growth be cut from a shade branch of a beech tree, there will according to our experience generally be found to be four, occasionally only three, more rarely five leaves upon it. The accompanying Plate II. represents a number of such sprays, the typical forms being I. and II. Looked at from the back we shall call the leaves that fall on the right of the stem of the spray, right-hand leaves, and on the left of it, left-hand leaves. Measuring from the top of the spray down it, the leaves will be called first, second, third, etc., leaves. The leaves are almost invariably—in 99 per cent. of the cases observed—on alternate sides of the stem. 206 such sprays were gathered from the beech trees growing on Highmore Common, not far from Nettlebed on the Chilterns, by Dr Alice Lee and myself—the bulk from very large forest trees. Of these sprays 98, instead of 103 the half, had the first leaf on the right-hand side. In one case the third leaf was the first on the right-hand side; in the remaining 107 cases the second leaf was the first on the right-hand side. On the left-hand side there were 108 cases of first leaf and 98 cases of second leaf. We think we may therefore assert that the first leaf is as likely to be on the right as on the left side of the stem of the spray. The first and second leaves of the spray are both much larger than the third and fourth leaves, and there is a marked differentiation between the first pair and the second pair. This differentiation is so obvious, the second pair being in many cases quite dwarfs, that for the first paper* dealing with beech leaves we did not collect this secondary pair, and such pairs were therefore not included in the countings of the veins. The object of the present note is to test (i) whether serious error was introduced by disregarding the differentiation of the members of the first pair, and (ii) what effect the inclusion of the secondary leaves would have upon the homotyposis.

(iii) Investigating first the difference between the first leaf on the right and the first on the left without regard to order, and dealing with the same character as in the earlier investigation, i.e. the total number of veins on both sides of the main ridge of the leaf, we find :

	Mean	Standard Deviation
First Left-hand Leaf...	$15{\cdot}432 \pm {\cdot}075$	$1{\cdot}589 \pm {\cdot}053$
First Right-hand Leaf	$15{\cdot}495 \pm {\cdot}074$	$1{\cdot}585 \pm {\cdot}053$

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* "Homotyposis in the Vegetable Kingdom." *Phil. Trans.* Vol. 197, A, p. 324.

There is clearly then no sensible differentiation between the number of veins or its variability when we pass from the right to the left-hand side of the stem.

Next dealing with the leaves taken in order down the stem, and without regard to their right or left-handed position, we have:

	Number	Mean	Standard Deviation
First Leaf ...	206	15·684 ± ·071	1·505 ± ·050
Second Leaf ...	206	15·257 ± ·076	1·612 ± ·054
Third Leaf ...	205	13·098 ± ·096	2·034 ± ·068
Fourth Leaf ...	145	10·559 ± ·110	1·968 ± ·078
Fifth Leaf ...	23	8·348 ± ·204	1·448 ± ·144

The mean of all the first and second leaves together may be compared with the Great Hampden series of 1900, also from the Chilterns:

	Mean	Standard Deviation
Highmore Beeches ...	15·471	1·574
Great Hampden Beeches	16·106	1·735

Considering the difference of localities, of season and class of tree, these results appear to be in reasonably close agreement, and enable us to judge how far any serious error was introduced into the Hampden results by the hypothesis that the large, i.e. first or second leaves on the spray, were undifferentiated. The Hampden leaves have clearly more veins, there is a sensible difference of ·6 in the mean, not very great, but sufficient to show that we had properly excluded the third and fourth leaves, when we collected. In the next place there is a sensible differentiation as we go down the stem, most marked when we pass from the first two leaves to the third, fourth and fifth, but hardly of great importance when we consider only the first and second.

If we treat as we did in the Hampden series the first two leaves as homotypes and work out their correlation we find:

Homotypic Correlation of first two leaves

$$\rho = ·504 \pm ·025.$$

Now let us work this out, allowing for the differentiation between the two leaves. Using the formula given in *R. S. Proc.* Vol. 71, p. 302, i.e.:

$$r = \rho \frac{\sigma^2}{\sigma^2 - \sigma_M{}^2} + \frac{\sigma_M{}^2}{(m-1)(\sigma^2 - \sigma_M{}^2)},$$

we have:

$$\rho = ·5042,$$

$$\sigma^2 = 2·47731, \quad \sigma_M{}^2 = ·045582$$

$$\sigma^2 - \sigma_M{}^2 = 2·34839. \quad m = 2.$$

Whence we find:

$$r = ·5513.$$

The actual value given for homotyposis in beech leaves of the Hampden series being ·5699, it will be seen that only a small change has been made by allowing for differentiation in the present results from the Hampden value. The simple explanation of this undoubtedly being that our leaves were almost entirely, owing to our method of gathering, the *first* and not the second leaves of the year's growth.

But the present investigation allows us to go a stage further, and to find the homotyposis in beech leaves supposing we take all leaves and not merely the two first leaves of the year's growth. We have 144 sprays* with four leaves on, five leaves are so rare that we cannot use the fifth leaf. Let us find the homotyposis of the series as a whole, correcting for differentiation.

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* In the case of the 145 sprays with fourth leaves recorded, there was one in which a third leaf was not available for counting.

We have : $\rho = \cdot 0300 \pm \cdot 0162.$

In other words, when we do not pay attention to differentiation the homotyposis is almost zero. Clearly the small leaves on the spray could not be disregarded even by a most careless gatherer, without the result being very manifest when the correlation is determined.

Now let us allow for this gross case of differentiation by the above formula. We have

$$\rho = \cdot 0300 \pm \cdot 0162,$$
$$\sigma^2 = 7\cdot 28052, \quad \sigma_M{}^2 = 3\cdot 88274,$$
$$\sigma^2 - \sigma_M{}^2 = 3\cdot 39778. \quad m = 4.$$

Hence :
$$r = \cdot 0643 + \cdot 3809$$
$$= \cdot 4452.$$

Considering the comparative paucity of the material—only 144 sprays—I think this result may be considered fairly satisfactory. Namely, we find, that judged by the first two leaves the homotyposis is ·55, agreeing closely with the earlier determination ; judged by the first four leaves of the spray the homotyposis is ·45. The probable error of either result is certainly not less than ·04 to ·05*, and we conclude that the homotyposis in beech leaves cannot diverge much from ·5. Experience seems to show that the wider range of homotypes taken, if we allow for differentiation, the better the result will be. The present paper is also of interest as showing that a slight differentiation such as that between the first and second leaves, even if it should escape detection, would not radically modify, still less vitiate the results obtained. To get final numbers probably 1000 sprays of four leaves ought at least to be dealt with. The present study, however, will indicate how the student of homotyposis can investigate and allow for differentiation due to position. Other instances are given in the memoir in the *R. S. Proceedings*, Vol. 71, pp. 288–313.

(iv) A paper has been recently published by Miss Tine Tammes† in which two tables are given for the number of veins on beech leaves, having regard to their position on the year's shoot (*Jahrestriebe*). The authoress gathered 15 shoots with 9 leaves and 6 shoots with 8 leaves,—all off the *same* tree. She sought shoots with the same number of leaves as they had internodes : "Diese waren, obgleich die Zahle der Internodien bei dem verschiedenen Trieben ziemlich stark variirt, an dem grossen Baume ohne viel Mühe zu finden" (p. 78). Further the shoots taken were those which had the greatest number of internodes.

She found for this single tree :

Position of leaf from base of shoot	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Mean No. of veins on 15 shoots	9·8	11·7	13·1	13·5	13·1	12·7	11·9	10·6	9·5
„ „ 6 shoots	10·0	11·7	13·3	13·8	13·7	12·8	12·0	11·0	—

Now what is quite clear from this table is that (i) the nature of the shoots dealt with by Miss Tammes is both for number of leaves and number of veins to the leaf entirely different to what would be obtained by a random collection of year's shoots on the Chiltern beeches. That (ii) had she made such a random collection, her law of periodicity in growth would not have received confirmation from the beech tree at all.

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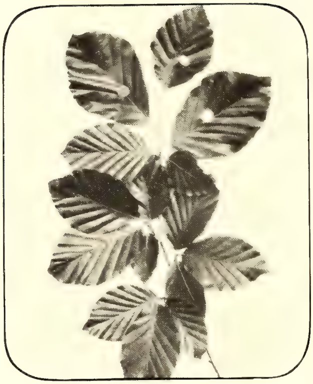
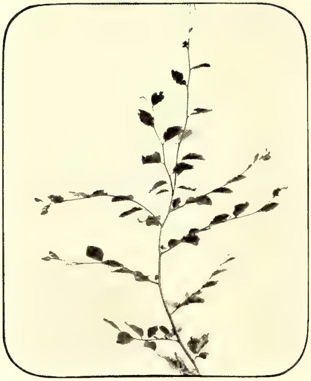
* For example, with a deviation of ρ from ·03 equal only to about its probable error, the first term in r will be raised to ·10 instead of ·06 and thus r would be sensibly ·5.

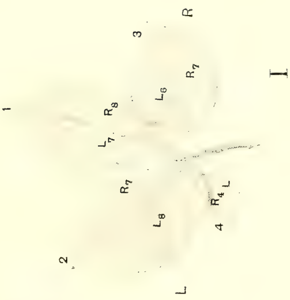
† *Verhandelingen der Koninklijke Akademie van Wetenschappen te Amsterdam* (Tweede Sectie), Deel IX. Die Periodicität morphologischer Erscheinungen bei den Pflanzen, pp. 1—148. Maart, 1903.



'Shade' Branch.



'Sun' Branch.



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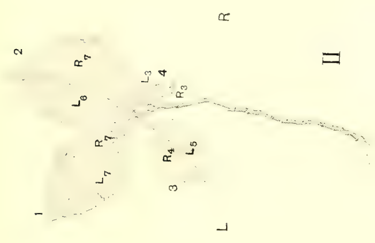

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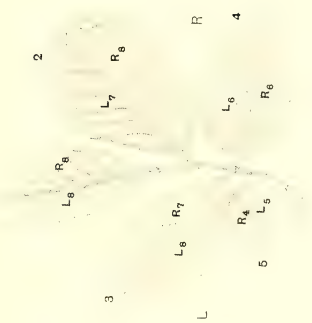

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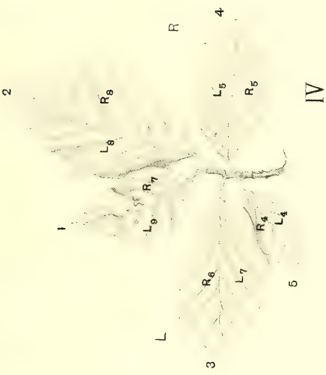

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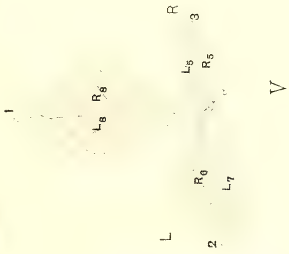

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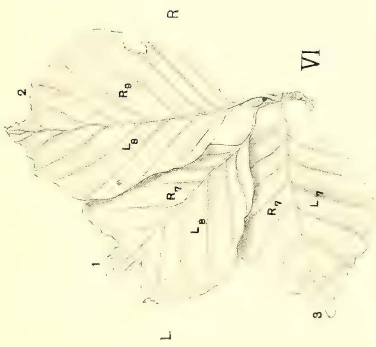

VI

There seems therefore considerable danger both in drawing conclusions from *selected* shoots of a *single* tree in a problem of growth and further in citing such results as an argument as to homotyposis. Probably, but we have no certainty for it, Miss Tammes in selecting shoots with 9 leaves, really made a selection of 'sun' branches as distinguished from 'shade' branches, but whether her results are universally true for the leaves on all such branches of all beech trees, it is quite impossible to say until a large number have been examined. In the case of the big trees such as we have dealt with from Hampden and Highmore, the task of collecting year's shoots from 'sun' branches will not be an easy one, for in the majority of cases they are very inaccessible. Whether the homotyposis of 'sun' branches differs from that of 'shade' branches, it is impossible to say ; the larger number of leaves to the shoot on the former, however, would make them better material for homotypic investigation.

(v) It may perhaps not be out of place to note here that since the first memoir on homotyposis was written we have been able to get a short series of 150 woodruff sprays from a lane at Horsham, Sussex. The woodruff was in flower and the whorls were counted from the flower downwards. As compared with the Great Hampden* series we found:

	Mean number of branches	Standard Deviation
Great Hampden ...	6·9	·93
Horsham	6·7	·84

The correlation between position and number of branches was ·26 and the homotyposis allowing for this differentiation was ·32. This is a very sensible increase on the ·17 of the original Hampden investigation, but while the number of whorls to the spray at Hampden was on an average 7 and might reach 10, the mean number at Horsham was 4·5 and never exceeded 5. Hence the material did not provide a good determination of the relationship between number of branches and position of the whorl. What it does suffice to show is that the Hampden series was justly described as having a value much reduced by neglect of differentiation. We should be very glad if any reader of *Biometrika* would provide us with 400 to 500 healthy sprays of woodruff after the plant has ceased to grow in the autumn of next year.

Description of Plates.

Plate I. Illustrations of the so-called 'sun' and 'shade' branches of the beech.

Plate II. Backs of typical beech leaf sprays. I and II. Usual forms of spray, with four leaves and indicating the marked differentiation between first and second pairs of leaves. II and III. Seldom forms with five leaves. V and VI. Less seldom forms with three leaves only. The letters *L* and *R* indicate the left and right-hand side of the back of the leaf and the subscript figures the number of the veins. The larger number gives the order of the leaf on the spray stem.

III. Albinism in Sicily and Mendel's Laws.

It has been suggested by Castle (1) that albinism in Man behaves in accordance with Mendel's Laws of Inheritance, and the suggestion is considered probable by Bateson (2). In a recent paper Garrod (3) has endorsed the same view, and has cited the work of Arcoleo in support of it. Arcoleo's work (4) records 62 cases of albinism observed in Sicily, the greater number in the province of Palermo. Three of the albinos recorded were produced by albino parents, the rest had normal parents. In ten cases it is known that the parents were pigmented, but it is not known whether they produced pigmented children in addition to the albinos.

The forty-nine remaining cases were distributed among twenty families, which contained altogether 133 children. Now, on the Mendelian hypothesis, that albinism and possession of pigment are allelomorphic characters, albinism being recessive, the marriages which can give rise to albino children are of two kinds only, namely (1) those between albinos of any ancestry, who are by the hypothesis "gametically pure recessives," and (2) those in which each individual has some albino ancestry, and is a "heterozygous" product. Marriages of the first kind should produce albinos only, while a quarter of the children resulting from marriages of the second kind should be albino, the rest being pigmented. Neither of these expectations is justified by Arcoleo's record. The three albinos produced by albino parents belonged to one family, and it is stated that "Gli antenati furono *tutti* bianchissimi," implying a considerable amount of albino ancestry; yet this family contained two pigmented brothers! Again, the most probable number of albinos among the 133 offspring of pigmented parents, all of whom are known to be capable of producing *some* albinos, is 33·25, and the Standard Deviation of this expectation is $\sqrt{\frac{1}{4} \times \frac{3}{4} \times 133} = 4{\cdot}94$. The observed number of albinos, namely 49, shows an excess of 15·75, or about 3·2 times the standard deviation, over that predicted by the Mendelian hypothesis. The odds against any result as large or larger than that observed, if the hypothesis be true, are nearly 2000 to 1; and although this degree of improbability may not be held by some to disprove the hypothesis, it certainly ought not to be adduced as evidence in support of it.

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* The Great Hampden Lane gave no woodruff when examined this autumn, but the hedges had been recently cut down and the banks trimmed.

The occurrence of segregation in a non-Mendelian proportion is exactly paralleled by the behaviour of the character "waltzing" as opposed to normal walking in mice, recorded by von Guaita and Darbishire.

The one fact which is not in apparent contradiction to Mendel's hypothesis is the behaviour of six albinos who married pigmented persons. One marriage was sterile; the other five produced altogether 24 children, all pigmented.

Taking these records in conjunction with the work of Cuénot (6) and Darbishire (5) on the inheritance of albinism and of other characters in mice, we see that the disappearance of a character such as albinism in the offspring resulting from a cross between an albino and a pigmented individual, and the reappearance of albinism in a portion of the grandchildren, produced when the immediate offspring of the cross are mated, may be associated with very different conditions of the albinos. Cuénot and Darbishire have both shown that the colour of the young produced by a cross-bred albino mouse, paired with a coloured mouse, depends partly on the colours exhibited by the ancestors of the cross-bred albino, thus showing clearly that such an albino, although it should be a "pure recessive" in Mendel's sense, is not gametically pure. Among mice there is no certain record of cross-bred albinos so impure that when paired together they produced pigmented young; the case of the family recorded by Arcoleo is therefore of great interest, as showing that in Man even this degree of "gametic impurity" may exist in albinos.

These results show how necessary it is that the phenomena of alternative inheritance should be studied in the light of fuller experimental knowledge concerning the correlations between cross-bred individuals and their ancestors; they show the futility of attempting to express such phenomena in terms of formulae based on the unproved hypothesis of gametic purity.

Finally I would urge on those who have opportunity the great value of a full study of albinism in Sicily. In the province of Palermo, from which many of Arcoleo's cases are drawn, the percentage of accepted soldiers of pure blonde type ("con capelli biondi e con occhii celesti") is given by Livi (7) as 2·1; that of men "con capelli biondi o rossi e con occhii celesti o grigi" is 3·8. Albinos are naturally exempt from military service, because of their abnormal eyes, and therefore do not appear in Livi's table. During a recent visit to Sicily, when I walked over a good deal of country round Palermo with an artist friend, my attention was continually called, not only to albinos, but to the extraordinary fairness of many blonde persons, who were still slightly pigmented. It would be of great interest to know whether these blondes are more often related to albinos than are persons of the darker, more usual type.

W. F. R. W.

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1. CASTLE, W. E., and FARABEE, W. C. Notes on Negro Albinism. *Science*, 1903, XVII.
2. BATESON, W. The Present State of Knowledge of Colour-heredity in Mice and Rats. *Proc. Zoolog. Soc.* 1903. Vol. II.
3. GARROD, A. Ueber chemische Individualität und chemische Missbildungen. *Pflügers Arch. f. d. gesammte Physiologie*, XCVII (1903).
4. ARCOLEO, G. Sull' Albinismo in Sicilia. *Archivio per l' Antropologia*, I (1871).
5. DARBISHIRE, A. D. On the Result of Crossing Japanese Waltzing with Albino Mice. *Biometrika*, Vol. III, pp. 1—51.
6. CUÉNOT. L'Hérédité de la Pigmentation chez les Souris. *Arch. Zool. Exp.* (Notes et Revue), 1902. Sér. 3, T. X. No. 2.
7. LIVI, R. *Antropometria militare.* 4to. Roma, 1896.

IV. A Mendelian's View of the Law of Ancestral Inheritance.

It is a very thankless task to try and correct every mis-statement that untrained minds make when they attempt to deal with a statistical problem. But one can only hope that the persistent exposure of the blunders made by non-statistically trained biologists, when they treat problems of heredity, may ultimately produce some effect. To the statistician nothing is more obvious and intelligible than the independence of the correlations, variations and means of characters. A knowledge of any one of the three involves no knowledge of the other two. Again, equally distinct in his mind are the multiple regression coefficients and the correlations. No practised biometrician could for a moment confuse with the ancestral correlations the multiple regression coefficients, which appear when we calculate the most probable deviation of an individual from his own type with the known deviations of his ancestors from their types; still less would he confuse a correlation coefficient with the number of offspring that take after a parent or grandparent! It is difficult to understand at all the attitude with which a biologist like Professor Castle* approaches a problem in inheritance, but it is summed up in the words that he has not the least idea that there is any distinction between a correlation, a multiple regression coefficient, and the number of individuals who may take after an individual ancestor!

Mr Francis Galton published in his *Natural Inheritance* (p. 136), "with hesitation" the following statement "consequently the influence of the individual parent would be $\frac{1}{4}$, and of the individual grandparent $\frac{1}{16}$ and so on."

In his work on Bassett Hounds, Mr Galton subsequently extended this principle by supposing that of the "heritage" as represented by all the offspring together, $\frac{1}{4}$ of the total would on the average have the character of each parent, $\frac{1}{16}$ that of each grandparent, $\frac{1}{32}$ that of each great grandparent, and so on. This statement is obviously different from that in *Natural Inheritance*, where Mr Galton is treating of a blending character. It deals with alternative inheritance. From these numbers Professor Castle deduces "Galton's Series." He calls the parental influence ·50, the grandparental influence ·25, the great grandparental ·125 and so on. I presume that he understands by this the proportions in the total offspring who will be like each individual ancestor. Against these proportions Professor Castle puts a series which he calls "Pearson's

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* "The Laws of Heredity of Galton and Mendel, and some Laws governing Race Improvement by Selection," by W. E. Castle. *Proceedings of the American Academy of Arts and Sciences*, Vol. XXXIX, pp. 223—242.

Series," in which he has taken the correlation coefficients with a *single* parent or a *single* grandparent etc., as I have deduced them for man and horse as if they were quantities in the least comparable with the number of individual offspring. He remarks:

"Comparing Pearson's series with that of Galton, we see that the parental influence is reckoned as substantially the same by both Galton and Pearson, but that Pearson assigns a much greater influence to the more remote ancestors than does Galton*."

Had Professor Castle merely added up the numbers he gives in this "Pearson's Series" he would have realised that they could not possibly represent what he states them to do; for the four grandparents alone would have had more offspring "like" themselves than the total number of offspring!

Now the Law of Ancestral Heredity as stated by me gives absolutely no means of ascertaining the number of offspring "like any given ancestor"; and if we measure parental influence by intensity of *correlation*, we should have:

	Pearson's Series	Galton's Series
Parental Influence	1/2	1/3
Grandparental Influence	1/3	1/9
Great grandparental Influence	2/9	1/27
Great great grandparental Influence ...	4/27	1/81

whence the complete misrepresentation of Professor Castle will be obvious.

After calculating a table which he says gives the distribution of the offspring of a cross between grey and white mice for 7 generations on Galton's Law, Professor Castle continues:

"The observed numbers, it is evident, agree no better with one of Pearson's series than with that of Galton. The discrepancies noted between observed and calculated will remain and even be accentuated if we replace Galton's series with one of those† suggested by Pearson. For the result will be unchanged in generation II, but the calculated numbers will in most cases diverge still more from the observed ones, in the later generations, because Pearson attaches more weight to the remoter ancestors than does Galton."

Now I suppose Professor Castle had some idea in his mind when he penned these lines, but so far as I can understand the Law of Ancestral Heredity as I have myself enunciated it, the produce of a grey mouse and a fawn mouse might be on the average a green mouse without that Law having anything to say on the point. From it you cannot possibly deduce what number of the offspring of any generation will be like this or that ancestor. It is not a law of types, but of the distribution of deviations from type, and this is a very different thing indeed.

The Law of Ancestral Heredity, as I have repeatedly stated ‡, makes no assumption as to the mean character of any generation; it gives no statement whatever as to the number of offspring who are like any individual ancestor. What it does give us is this: the means of determining the probable deviation of any individual from the *type of his own generation*, when we know the deviations of some or all his ancestry from the types of their respective generations. What then is the simple relation of my Law of Ancestral Heredity to Galton's series of $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$ etc.? It lies in the following hypotheses: (i) Galton supposes the type of each generation to remain the same, and expressly states that he is *dealing with a stable population*. Notwithstanding Galton's own statement as to his series holding for a stable population, Professor Castle does not hesitate to apply it to a cross which produces a totally different population! My types may alter and do alter in any way from one generation to a second. (ii) Galton supposed that we may apply his series not only to the deviation of an individual from type, but to the "whole heritage," he divides the offspring up into groups of individuals following special ancestors. This is an extension I have expressly and repeatedly disagreed with. I look upon such a distribution as not falling under the Law of Ancestral Heredity at all, but as part of the Theory of Reversion or of Alternative Inheritance. My agreement with Galton consists in the general conceptions (*a*) that the deviation of an individual from the type of his own generation depends ultimately on the deviations of his particular ancestors from their types, and (*b*) that the proportions of such deviation from type contributed by each generation of ancestry diminish in a geometrical series. This series is not Galton's. It may be deduced from the ancestral correlations, and in the case of man, horse and dog the series are within the limits of errors of observation identical. It is these ancestral correlations (which have no relation whatever to type, and are only connected with the regression coefficients which give the proportions of the deviation by complex determinantal relations) which Professor Castle cites, and states do not agree with the numbers of coloured mice that von Guaita found descended from albino-grey crosses in successive generations!

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* p. 224, *loc. cit.*

† Professor Castle quotes the two series I have given in *Biometrika*, Vol. II., p. 222, the one as the best geometrical series, and the other as a close series, in which round numbers were taken.

‡ *R. S. Proc.* Vol. 62, pp. 387 *et seq.*, where all the deviations are expressly said to be measured from the type of each generation, so that any modification of the type may be allowed for. Also in *Biometrika*, Vol. II., p. 217, where we are again told that the deviation is from the type of its generation, and are expressly warned (p. 226) that no assumption is made that the mean of the forecasted character is identical or not with any of the means of the foreknown characters. These papers are actually cited by Professor Castle.

Now Professor Castle was perfectly free to ignore my work, or to confess frankly that he could not understand it, but he commits a grave breach of scientific decorum when in a paper, not taking hasty journalistic form but published by the American Academy, he states that "the test of von Guaita's mice is conclusively in favour of Mendel's Law and against the law of ancestral heredity," and yet shows that he has either not read, or not been capable of properly citing, the two papers in which the meaning of this law is discussed. Either Professor Castle is so ignorant that he does not know that a coefficient of correlation cannot be a group frequency; or, he has directly misquoted my memoirs because any form of argument suffices for the audience he wishes to appeal to. It is a fundamental canon of scientific discussion that, if you wish to contradict a man's results, you should know what those results are and cite them correctly. It is a breach of scientific decorum to assert that a man's theory is opposed to certain facts, when you have demonstrably not the faintest notion of what that man's theory is, or how his results are reached.

I stated in my paper of 1903 on the Law of Ancestral Heredity that "as far as the available data at present go, inheritance coefficients for ascending ancestry are within the limits of observational error represented by a geometrical series and by the same series." Professor Castle remarks:

"It should be observed that the 'available data' upon which principally Pearson bases his conclusions consist of two cases of pigment inheritance, one in man, the other in the horse. A third well-known series of this sort has not been utilized by Pearson, though our information about it is much more complete and precise than that about either of the other two. I refer to our statistics about colour inheritance in mice recorded by von Guaita*."

Now there are two points to be considered here. Professor Castle states (i) that the information is far more complete and precise, and (ii) that it is available for discussion by aid of the Law of Ancestral Heredity. Any one who has compared the total number of original parents or of offspring in any generation in von Guaita's statistics will realise that they are absolutely incomparable with the numbers we possess for man, horse or hound. They are also statistically insufficient to give correlation coefficients significant having regard to their probable errors. Further, the data given, as in almost all Mendelian categories, are so wanting in precision that it is impossible to measure the deviations from the mean of any generation and so obtain the correlations. Not until far more precise classifications are made than von Guaita provides would the material be "available."

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* Castle: *loc. cit.*, p. 224.

In the next place, to what material can the ancestral law at present be applied? It was perfectly open to Professor Castle to examine the conditions under which its results so far have been reached. They are stated with perfect precision in my memoir of 1898, and are (i) the absence of assortative mating, (ii) the absence of in-breeding and of selection. Now in von Guaita's experiments he got mice in which the ancestry had been assortatively mated for generations: he first put like to like or made a perfect coefficient of assortative mating; and then he crossed like with unlike, or made the coefficient of assortative mating negatively perfect.

This coefficient is taken *zero* throughout my memoir on the law of ancestral heredity, and the reader is told that the author hopes to deal in a later paper with the influence of assortative mating and in- and in-breeding. Notwithstanding this direct warning Professor Castle does not hesitate to speak of the Law of Ancestral Heredity as applicable to von Guaita's data, and while the propounder of that law has not yet been able to master the difficulties of the analysis which arises when intense assortative mating and generations of in-breeding are taken into account, the biologist remarks that the observed numbers, "it is evident," disagree with Pearson's series. Had I been able to master the analysis, von Guaita's data would not have provided the material upon which the correlations could be based, and so the law itself tested; they are simply not "complete and precise" enough.

Professor Castle, as I have already stated, reaches his result by taking my correlation coefficients for inheritance in man and horse, and asserting that they give the proportions of offspring who will be "like the ancestors." As I have before indicated, the typical ancestor might be blue and the typical offspring yellow without this having any bearing at all on the correlation coefficients. Personally I have no means of determining whether the law of ancestral heredity holds or does not hold for coat colour in mice. The theory has not yet been worked out in a form covering von Guaita's cases, and data are only at present being collected complete and precise enough for the purpose.

In the face of these facts I directly challenge Professor Castle to confess that he did not when writing his paper know what a coefficient of correlation was, and that he was thus incompetent to discuss the application of the law of ancestral heredity to mice; or else to show that either the correlation coefficients, or, if he likes better, the multiple regression coefficients, which lie hidden in von Guaita's data can really be extracted therefrom and are inconsistent with the values which I have found for man, horse and dog, when allowance is made for assortative mating and selection. I do not see that any other course is open to Professor Castle, after his statements that "it is evident" that the numbers do not fit my series and that "it is evident" that some fundamental defect exists in the "law of ancestral heredity." It is time that some check should be administered to this irresponsible and ignorant criticism of biometric methods, a criticism which can confuse a group-frequency—i.e. a number of individuals —with a correlation coefficient, a relation between deviations from type in individuals; and I therefore directly challenge Professor Castle to justify his statements, or failing that I call upon him to retract them.

These statements are as follows:

(*a*) Pearson's Law of Ancestral Heredity can be applied to test von Guaita's data for mice, and,

(*b*) When so applied, "it is evident" that it does not fit them.

K. P.

VOLUME III MARCH AND JULY, 1904 NOS. 2 & 3

EXPERIMENTAL AND STATISTICAL STUDIES UPON LEPIDOPTERA.

I. VARIATION AND ELIMINATION IN *PHILOSAMIA CYNTHIA*.

BY HENRY EDWARD CRAMPTON, PH.D.

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Prefatory Statement.

THE present paper consists of an account of a detailed study, by means of statistical methods, of the facts of variation and of the relation between variation and selection in the pupae of the Ailanthus silk-worm moth, *P. cynthia.* The observations here recorded were made more than four years ago, and they have been continued and extended in subsequent years upon the same and other species of Saturnids. Naturally the scope of the later investigations has materially widened, and in addition to the fundamental problem mentioned above, the existence of sexual selection has been examined, as well as a host of other questions which relate to the process of evolution and its factors. Among these may be mentioned the comparative variability of the two sexes, the variability of individuals at various stages in their life-history, the comparative variability of native and introduced species, and the relation between an introduced species and the same species in its original habitat. The problem of inheritance in pure species has likewise been under investigation, and attempts have been made to cross various species in order to ascertain whether heredity in such cases follows the principles of Mendel.

The lepidoptera afford extremely favourable material for investigations of the above nature, for they can be obtained in considerable numbers, and they may be bred with not too great difficulty. And a qualification of special importance is to be found in the sharp division of their life-history into three well-demarcated periods, each characterized by peculiar external and internal relations. It is of course clear that the structural relations of the imago must be totally different from those either of the larva or of the pupa, and it is equally evident that these forms have entirely diverse relations to the "environment" at large. Therefore the problem of selection derives an added interest from the comparison of elimination as it appears at one stage with that of another period.

Furthermore the imago and the pupa possess attributes which give to each a peculiar value. The former enters upon its final period of life with a rigid and unchangeable organization, incapable for the most part of structural alterations as the result of "functional adaptation." The pupa excites still greater interest on account of its inability to "use" its various organs in any way. Life and adaptive response are here minimized to their lowest values; and helplessly subject to environmental influences and constitutional weakness the pupa awaits the period of renewed activity which culminates in metamorphosis.

It is from the very nature of the case impossible to present the results of the several studies carried forward during the past few years in a simple and condensed form. Merely to enumerate the statistical data which have been accumulated would trespass beyond even liberal bounds. Therefore it has been deemed best to offer the statement of problems and results in a series of papers, each dealing with a well-restricted division of the whole field. The present long-deferred account, which initiates this series, indicates as well the point of departure for the later investigations.

I. *Introduction.*

The following account is a statement of the results of an examination into the occurrence of "natural selection" in the case of over-wintering pupae of *Philosamia cynthia,* as this species occurred in New York City in the year 1899. It is concerned, therefore, with the existence of a definite relation between elimination on the one hand, and the extent and character of variation on the other; and particular attention is directed towards ascertaining the real basis for the selective process.

In previous years, when large numbers of the cocoons and pupae of this species had been collected for other purposes, it had been noticed that a great many cocoons contained individuals which had died, although they were apparently perfectly normal. And it also appeared that many of the normal living pupae failed to metamorphose perfectly, whether they were kept in the laboratory or out of doors. The opportunity thus offered was taken for an examination into the phenomena of elimination for two successive developmental periods. The first, or period of *pupal elimination,* extends from the formation of the cocoon and pupation to the beginning of the formation of the imago. The second period immediately supervenes, and, as the period of *pupal-imaginal elimination*, is marked by the deeply-seated structural and physiological changes of metamorphosis. The reduction of the second period, which results in the weeding out of certain of the *adult* moths, is none the less entirely dependent upon the ability of the *pupa* to accomplish successfully the production of the imago. On this account, as well as for the reason that the moth is constructed in strict accordance with the lines of the pupa, the examination into selection of this second period may justly be conducted with reference to pupal characters. To the two sections in the following account which treat separately these periods of elimination, a third section is added, which deals briefly with the comparative variability of the pupae of the two sexes.

II. *The Material and its Treatment.*

In December, 1899, all the accessible cocoons were obtained from a small area of less than one acre in the upper part of the City of New York. The cocoons were found principally upon Ailanthus trees, the favourite and original food-plant, where clusters of twenty-eight or thirty were sometimes to be found upon a single branch. Many were taken from vines and fences near these trees, and still others were picked up from the ground whence they had fallen from the trees. It may be noted in passing that these last, far from being unfavourably affected, contained as many living pupae as those which remained attached to the trees.

The total number of cocoons was 1090. Upon examination of the contents, 55 (4·8 °/$_{\circ}$) were found to contain dead and shrivelled individuals which had failed to pupate. Ninety-three contained pupal cases from which the moths, probably of an interpolated summer brood, had escaped, or where, in nine cases, the fully-formed imago had been unable to emerge from the cocoon. Out of the 942 remaining, 623 had pupated, forming in most cases an entirely normal pupa, but they were dead. Thus only 319 "selected" individuals remained to provide for the continuance of the species.

Equal numbers of the dead and surviving pupae were carefully measured, as stated below, and the living ones were kept through the metamorphosis, care being taken to isolate them as this time approached. Only 181 (97 males and 84 females) produced perfect moths, 75 were imperfect to a slight degree, 38 were hopelessly malformed and finally 16 failed to metamorphose at all. The perfect imagines constituted only 16·6 °/$_{\circ}$ of the whole number of individuals which entered the cocoon, from which we may gain an idea of the severity of the conditions under which the quiescent pupa exists.

The comparison of the surviving pupae with an approximately equal number of dead pupae, and the comparison of the perfect survivors with the remainder of the group of survivors, has been based upon the following characters, numbering ten: first, two measures of the pupa as a whole, (1) the total length, the distance *A—B* in the diagram, and (2) the weight in milligrams; in the second place, a group of characters of the immovable anterior part of the pupa, which may for convenience be termed the "bust," and which extends back to the posterior ends of the wing-cases, at the level of the line between the fourth and fifth abdominal segments. The characters in question are (3) the length of the bust, the line *A—C*, (4) the width of the bust, the line *D—E*, (5) the dorso-ventral depth of the bust, the perpendicular line at the point *F*. From these measures were determined (6) the frontal proportions of the bust, as the ratio between the width and length, and (7) the sagittal proportions, as the ratio between the length and the depth of the bust. In the third place, certain measurements were made of a typical organ, the left antenna, namely (8) the length, the line *H—I*, and (9) the width, as the line *J—K*; from these were determined (10) the proportions of the antenna. All the measurements are in mm.

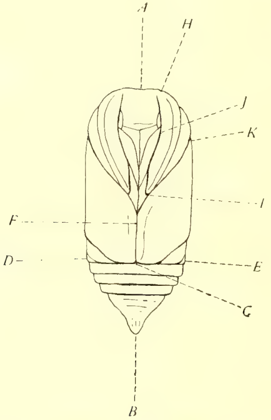


Fig. 1. Diagram of the Saturnid Pupa.

Of these characters two must be omitted in considering elimination of the first period, namely, length and weight, for after death evaporation and the consequent shrinkage of the free abdominal segments render these characters useless. While it is possible that alterations in the characters of the bust may follow death, thus invalidating any comparison between dead and living pupae, these alterations if indeed they occur, must in the nature of the case be very slight. We shall have occasion to recur to this point below. But at any rate elimination of the second period need take no account of this possibility. The antennal characters remain unchanged after death.

It will be seen that the "length" of the antenna is only a convenient measure approximating to the real axial length, which dimension it is almost impossible to measure directly. From this it follows that the determination of the antennal proportions is likewise only a convenient approximation, and the value of these characters needs to be further considered below.

Following the usual procedure, the determinations of every character in each sex were classified, and the frequency curve or polygon was plotted. It will be seen that each sex will have for every character five groups: all pupae, surviving pupae, dead pupae, perfect survivors, and the survivors which fail to metamorphose perfectly, which last we may term the imperfect survivors. The characters of the whole group need not concern us at this juncture. Now the comparison between the surviving and dead pupae, or between the two sub-groups of survivors, may be based upon the following constants: (1) the range of variation, (2) the mode, or value of greatest frequency, (3) the average value, or mean, (4) the standard deviation, or the index of variability, a constant found by squaring all the deviations from the mean, adding, extracting the square root, and dividing by the number of cases, and (5) the coefficient of variation, a constant of use in some connections, found by dividing the standard deviation by the mean, and multiplying the quotient by 100 to obtain a convenient whole number. Naturally the data at hand permit of much further mathematical analysis, particularly as regards the phenomena of correlation. For the present however attention may be directed only to the fundamental question as to the relation between variation and elimination and the comparison, for the sake of simplicity, may be restricted to the comparable determinations of the *mean* or average value of any given characters, and of the *indices of variation.*

Before passing to the actual facts, it must be pointed out that statistical treatment of the problem under consideration rests upon the assumption that when differences are found between two corresponding constants, belonging to two different groups, such differences are significant only when they considerably exceed the probable errors of the differences. For example, the bust length of perfect surviving pupae has a certain value for which we may determine the probable error, while the bust length of the comparable imperfect survivors has its mean value with a probable error. If the difference between the two mean values in question should exceed the probable error of such a difference, the chances that the difference signifies selection will be 68 to 32; if the difference exceeds twice the error of the difference the chances of significance are 95 to 5; while if the difference is in excess of three times the probable error the chances of significance are 975 in 1000. Therefore in the following account, a difference between two comparable determinations which lies between the values of 1ϵ and 2ϵ will be regarded as indicating that selection is here *possible,* when the difference lies between the values 2ϵ and 3ϵ it will be considered that selection is *probable*, while if it exceeds the value 3ϵ selection will be regarded as *certain*. As the same relation obtains between the differences and their probable errors in the case of comparable indices of variation, selection on the basis of variability may be denoted *possible*, *probable*, or *certain*.

III. *Pupal Elimination.*

A. *Males.*

The question at issue may be stated in the following form, Are the surviving pupae the same as those which succumb after normal pupation, or are they a selected group? The fact of limitation as regards the number of survivors stands unquestioned. Is elimination selective? Table I. gives the biometric constants for the total or unselected material.

TABLE I.

All Pupae.

	Males (264)		Females (356)	
Character	Mean	Standard Deviation	Mean	Standard Deviation
Bust, Length	18·1987 ± ·0318	0·7673 ± ·0225	19·3460 ± ·0292	0·8192 ± ·0207
„ Width	11·0466 ± ·0235	0·5675 ± ·0166	12·7182 ± ·0223	0·6262 ± ·0158
„ Depth	12·0031 ± ·0222	0·5357 ± ·0157	13·5117 ± ·0220	0·6178 ± ·0158
„ Frontal Proportions	60·8220 ± ·1041	2·5072 ± ·0736	65·8455 ± ·0850	2·3776 ± ·0601
„ Sagittal Proportions	66·0606 ± ·0868	2·0916 ± ·0614	69·9438 ± ·0716	2·0041 ± ·0506
Left Antenna, Length ...	11·2705 ± ·0230	0·5549 ± ·0162	11·5124 ± ·0255	0·5648 ± ·0180
„ „ Width ...	4·5829 ± ·0113	0·2730 ± ·0099	4·2221 ± ·0082	0·2293 ± ·0057
„ „ Proportions	40 7727 ± ·0890	2·1447 ± ·0629	36·6629 ± ·0682	1·9084 ± ·0482

In the following Tables II. and III. are given the numerical determinations for answering our first question. The surviving pupae number 134 as against 130 of the dead pupae. Although the facts appear with clearness in the numerical form, a brief verbal statement may not be superfluous. And in such a commentary we may examine separately two questions as to the nature of selection, whether namely it takes place if at all with reference to a certain type, or whether it expresses itself in the figures relating to variability.

In bust measurements, the survivors are found to be longer and narrower than the dead individuals. In both of these characters selection in type is *certain* according to the criterion established in earlier treatment. The survivors are also deeper (dorso-ventrally) than the eliminated pupae, and are selectively different

TABLE II.

Pupal Period. Selection in Type. Males.

Character	Mean; Survivors	Mean; Dead	(δ) Difference	(ε) Error of Difference	Proportion of δ : ε	Selection
Bust, Length	18·2313 ± ·0453	18·0924 ± ·0440	+0·1889	0·0631	> 2ε	Probable {almost certain
„ Width	10·9014 ± ·0322	11·1962 ± ·0320	−0·2948	0·0453	> 6ε	Certain
„ Depth	12·0471 ± ·0304	11·9577 ± ·0322	+0·0894	0·0441	> 2ε	Probable
„ Frontal Proportions	59·6865 ± ·1339	61·9923 ± ·1294	−2·3058	0·1850	> 12ε	Certain
„ Sagittal Proportions	65·9029 ± ·1206	66·2230 ± ·1243	−0·3201	0·1731	> 1ε	Possible
Left Antenna, Length ...	11·3514 ± ·0273	11·1870 ± ·0367	+0·1644	0·0457	> 3ε	Certain
„ „ Width ...	4·6844 ± ·0140	4·4784 ± ·0156	+0·2060	0·0209	> 9ε	Certain
„ „ Proportions	41·4105 ± ·1190	40·1154 ± ·1211	+1·2951	0·1696	> 7ε	Certain

TABLE III.

Pupal Period. Selection in Variability. Males.

Character	Standard Deviation; Survivors	Standard Deviation; Dead	(δ) Difference	(ε) Error of Difference	Proportion of δ : ε	Selection
Bust, Length	0·7780 ± ·0320	0·7441 ± ·0311	+0·0339	0·0446	< ε	None
„ Width	0·5535 ± ·0228	0·5424 ± ·0226	+0·0111	0·0321	< ε	None
„ Depth	0·5227 ± ·0215	0·5450 ± ·0227	−0·0223	0·0312	< ε	None
„ Frontal Proportions	2·2631 ± ·0932	2·1882 ± ·0915	+0·0749	0·1306	< ε	None
„ Sagittal „	2·0701 ± ·0852	2·1016 ± ·0879	−0·0315	0·1224	< ε	None
Left Antenna, Length ...	0·4686 ± ·0193	0·6218 ± ·0260	−0·1532	0·0323	> 4ε	Certain
„ „ Width ...	0·2412 ± ·0099	0·2645 ± ·0110	−0·0233	0·0147	> 1ε	Possible
„ „ Proportions	2·0423 ± ·0841	2·0470 ± ·0856	−0·0047	0·1200	< ε	None

with a high degree of probability. Naturally it follows from the foregoing that the survivors are much more slender in frontal proportions, and the difference between the two groups in this regard exceeds twelve times the error of the difference. In sagittal proportions, however, the narrower survivors are only *probably* different from the others.

Remarkably clear results follow from the comparison of the antennal characters. These organs are not only much longer in the survivors, and wider, but they are also stouter than those of the incapacitated pupae; and in all three characters the difference indicates selection with *certainty*.

Thus we see that in six of the eight characters under consideration, the surviving pupae evidence selection of type: that a typical condition, different from that of the dead pupae, characterizes those individuals which are physiologically "fit" to survive the vicissitudes of pupal existence.

When however we enquire if selection brings about the survival of the less variable individuals, the answer, though equally clear, is negative. Although in the depth of the bust, and in sagittal proportions, the dead pupae are more variable, they are less variable in the length, width, and frontal proportions of the bust. In none of these cases, nevertheless, does the difference exceed its probable error. There is in brief, no selection in variability. And when the facts relating to the antennae are examined, it appears that the survivors exhibit selection in length only with certainty, with possibility in width, and not at all in the variability of the proportionate measure. These statements will be found to be confirmed if the reader examines Table I. alongside Tables II. and III., thus comparing the unselected material with the selected.

B. *Females.*

After examining the facts relating to the female sex, we reach the remarkable conclusion that selection of a particular type occurs *in all eight characters.* In only one instance does the difference between the surviving pupae and the dead pupae fall below the error of the difference. Specifically, the survivors are longer, narrower, and deeper in the bust than the others, and they are also more slender in both frontal and sagittal proportions. Moreover their antennae are longer, wider, and stouter than those of the eliminated pupae. The actuality of selection is still further indicated by the fact that in all characters excepting the proportions of the antennae the variability of the former pupae is far less, and the significance is beyond the range of error due to random sampling. The same general conclusions are reached if we compare the survivors with the unselected material.

TABLE IV.

Pupal Period. Selection in Type. Females.

Character	Mean; Survivors	Mean; Dead	(δ) Difference	(ϵ) Error of Difference	Proportion of $\delta : \epsilon$	Selection
Bust, Length	19·5039 ± ·0363	19·1917 ± ·0443	+0·3122	0·0572	$> 5\epsilon$	Certain
„ Width	12·5949 ± ·0278	12·8388 ± ·0338	−0·2439	0·0437	$> 5\epsilon$	Certain
„ Depth	13·6007 ± ·0287	13·4250 ± ·0330	+0·1757	0·0437	$> 4\epsilon$	Certain
„ Frontal Proportions	64·5727 ± ·0954	67·0888 ± ·1079	−2·5161	0·1440	$> 17\epsilon$	Certain
„ Sagittal „	69·7727 ± ·0927	70·1111 ± ·1082	−0·3384	0·1424	$> 2\epsilon$	Probable
Left Antenna, Length ...	11·6426 ± ·0231	11·3833 ± ·0310	+0·2593	0·0386	$> 6\epsilon$	Certain
„ „ Width ...	4·3182 ± ·0102	4·1283 ± ·0126	+0·1899	0·0162	$> 11\epsilon$	Certain
„ „ Proportions	37·1250 ± ·1002	36·2667 ± ·0874	+0·8583	0·1329	$> 6\epsilon$	Certain

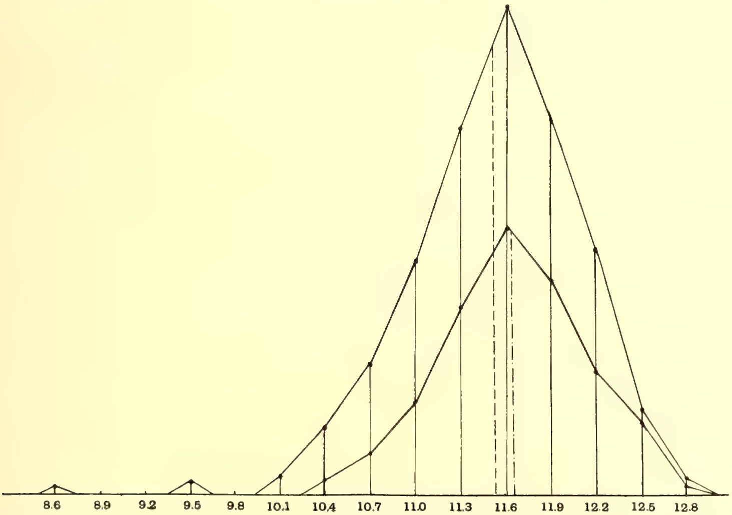
TABLE V.

Pupal Period. Selection in Variability. Females.

Character	Standard Deviation; Survivors	Standard Deviation; Dead	(δ) Difference	(ϵ) Error of Difference	Proportion of $\delta : \epsilon$	Selection
Bust, Length	0·7150 ± ·0257	0·8826 ± ·0313	−0·1676	0·0399	$> 4\epsilon$	Certain
„ Width	0·5477 ± ·0196	0·6731 ± ·0239	−0·1254	0·0309	$> 4\epsilon$	Certain
„ Depth	0·5643 ± ·0202	0·6567 ± ·0233	−0·0924	0·0308	$= 3\epsilon$	Certain
„ Frontal Proportions	1·8770 ± ·0674	2·1468 ± ·0763	−0·2698	0·1018	$> 2\epsilon$	Probable
„ Sagittal „	1·8230 ± ·0655	2·1535 ± ·0765	−0·3305	0·1007	$> 3\epsilon$	Certain
Left Antenna, Length ...	0·4711 ± ·0169	0·6177 ± ·0219	−0·1466	0·0276	$> 5\epsilon$	Certain
„ „ Width ...	0·2009 ± ·0072	0·2517 ± ·0089	−0·0508	0·0114	$> 4\epsilon$	Certain
„ „ Proportions	1·9703 ± ·0708	1·7387 ± ·0618	+0·2316	0·0939	$> 2\epsilon$	Reversed

One additional fact may be noted, which is that the type selection in the characters of the surviving females is in all cases in the same direction which it takes in the male sex. This correspondence is of decided significance.

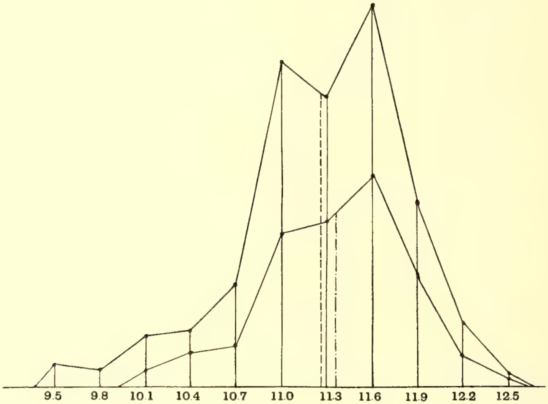
Fig. 2. Selection in Type. Pupal Elimination, Females.
Left Antenna Length (mm.).



															Total	m.
All Pupae	1	0	0	2	0	3	12	23	41	65	86	65	42	14	2	356	11·5124
Survivors							2	7	16	33	47	37	21	12	1	176	11·6426

Figures 2 and 3 illustrate the general nature of the selection in two cases by graphical representation of the original material and the selected survivors.

Fig. 3. Selection in Type and Variability. Pupal Elimination, Males.
Left Antenna Length (mm.).



												Total	m.	σ
All Pupae	4	3	9	10	18	57	51	67	32	11	2	264	11·2705	0·5549
Survivors			3	6	7	27	29	37	19	5	1	134	11·3514	0·4686

IV. *Pupal-Imaginal Elimination.*

We may now consider the nature of that reduction which takes place at the time of metamorphosis, and which, although dependent upon pupal abilities, is manifested only when the great changes at this time prove too severe a tax upon the strength of a large number of individuals which were able to survive throughout the earlier period of pupal existence.

It has been stated previously that only 181 out of the 310 survivors produce perfect moths. The rest were imperfect to a greater or less degree, or failed entirely to metamorphose, as follows:

	Perfect	Slightly Imperfect	Very Imperfect	Non-metamorphosed
Males	97 (72·3$^\circ/_\circ$)	14 (10·4$^\circ/_\circ$)	18 (13·4$^\circ/_\circ$)	5 (3·7$^\circ/_\circ$)
Females	84 (47·7$^\circ/_\circ$)	61 (34$^\circ/_\circ$)	20 (11·3$^\circ/_\circ$)	11 (6·2$^\circ/_\circ$)

It therefore appears that the females are the greater sufferers, although if the slightly imperfect individuals be counted with the perfect ones the males and females occur in about the same percentage*.

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* In studying the phenomena of sexual selection in *Samia cecropia* it has been found that a male which is imperfect to *any* degree will not copulate, while females which are slightly imperfect may sometimes copulate. These facts will be considered at length in a later communication.

The two characters of total length and weight are available in considering elimination of this period. It will be seen that beside the enquiry into the manifestation of selection of type and variability at metamorphosis, much additional interest arises when the relation between the selective effects of the two different periods of elimination is examined. Treatment of this period must therefore be two-fold.

TABLE VI.

Pupal-Imaginal Period. Selection in Type. Males.

Character	Mean. Survivors, Perfect	Mean. Survivors, Imperfect	(δ) Difference	(ε) Error of Difference	Proportion of δ : ε	Selection
Length	26·9329 ± ·0822	27·0137 ± ·1493	−0·0808	0·1704	< ε	None
Weight	1·9464 ± ·0154	1·9190 ± ·0307	+0·0274	0·0343	< ε	None
Bust, Length	18·3443 ± ·0482	18·1190 ± ·1027	+0·2253	0·1134	> 1ε	Possible {almost probable
„ Width	10·8856 ± ·0375	10·9702 ± ·0639	−0·0846	0·0740	> 1ε	Possible
„ Depth	12·0506 ± ·0345	12·0379 ± ·0632	+0·0127	0·0720	< ε	None
„ Frontal Proportions	59·4691 ± ·1503	60·2567 ± ·2590	−0·7876	0·2996	> 2ε	Probable
„ Sagittal „	65·7257 ± ·1355	66·3648 ± ·2475	−0·6391	0·2821	> 2ε	Probable
Left Antenna, Length ...	11·3896 ± ·0299	11·2514 ± ·0577	+0·1382	0·0649	> 2ε	Probable
„ „ Width ...	4·6908 ± ·0148	4·6676 ± ·0326	+0·0232	0·0358	< ε	None
„ „ Proportions	41·3351 ± ·1359	41·6089 ± ·2416	−0·2738	0·2771	< ε	None

TABLE VII.

Pupal-Imaginal Period. Selection of Variability. Males.

Character	Standard Deviation. Survivors, Perfect	Standard Deviation. Survivors, Imperfect	(δ) Difference	(ε) Error of Difference	Proportion of δ : ε	Selection
Length	1·2006 ± ·0581	1·3465 ± ·1056	−0·1459	0·1205	> 1ε	Possible
Weight	0·2259 ± ·0109	0·2769 ± ·0217	−0·0510	0·0242	> 2ε	Probable
Bust, Length	0·7032 ± ·0347	0·9265 ± ·0726	−0·2233	0·0804	> 2ε	Probable
„ Width	0·5482 ± ·0265	0·5765 ± ·0452	−0·0283	0·0523	< ε	None
„ Depth	0·5034 ± ·0243	0·5701 ± ·0447	−0·0667	0·0508	> 1ε	Possible
„ Frontal Proportions	2·1939 ± ·1063	2·3348 ± ·1831	−0·1409	0·2117	< ε	None
„ Sagittal „	1·9768 ± ·0957	2·2320 ± ·1750	−0·2552	0·1994	> 1ε	Possible
Left Antenna, Length ...	0·4375 ± ·0211	0·5289 ± ·0408	−0·0914	0·0459	> 1ε	Possible {almost probable
„ „ Width ...	0·2173 ± ·0105	0·2941 ± ·0230	−0·0768	0·0252	> 3ε	Certain
„ „ Proportions	1·9828 ± ·0960	2·1783 ± ·1708	−0·1955	0·1959	< ε	None

A. *Males.*

The pupae which produce perfect moths are found to be slightly shorter than those which fail to do so, and the former are slightly heavier also. In neither case, however, is the difference significant: there is no type selection in these characters.

The data relating to the bust measures are of some interest. The perfect survivors are longer, narrower, and deeper than the imperfect survivors, and they are at the same time more slender in frontal and sagittal proportions; in only the last two does selection appear with any degree of probability. It is highly important to observe that in all of these characters the perfect survivors bear the same relation to the imperfect survivors that the whole group of survivors does to the dead pupae. In brief, elimination of the second period appears to be a continuation of the earlier process of pupal elimination. Therefore the finally selected individuals are by far the longest, narrowest, and deepest, and at the same time the most slender ones of all that entered upon pupal existence.

In the antenna, continued selection appears as regards length, but while broader organs occur in the perfect survivors the difference between these and the others is insignificant. Finally, the antennae of the perfect survivors are slightly more slender, though here, too, the difference is of no account.

Although as we have seen there is no selection indicated in the type values of length and weight, when we compare the indices of variability in the two groups under consideration we find that the perfectly metamorphosing pupae are the less variable. Though this selection is but *possible* as regards the variability of length, a greater significance attaches to the difference between the variabilities in weight. In all the characters of the bust and of the antenna the perfect survivors are the less variable members of the whole group of survivors, but the difference between these and the other pupae is *probably* significant only in bust length, and *certainly* so only in antennal width.

To summarize briefly, we find that type selection at the time of metamorphosis occurs with probability only in the proportions of the bust and in antennal length, while very little selection of variability is evidenced.

B. *Females.*

The pupae which produce perfect moths are slightly shorter, and slightly lighter than the others, selection being *probable* in the first case, and *possible* (almost *probable*) in the second.

While in the males it was found that secondary elimination proceeded along the lines of pupal elimination, the pupae of the other sex show just the opposite relation. Specifically, the perfect survivors are shorter in the bust, and, though narrower as in the previous selection, they are less deep. In the proportionate measures especially they show the reversed nature of selection with the greatest clearness, for they are decidedly stouter in both frontal and sagittal planes with practical *certainty*, while as a result of the earlier pupal elimination the survivors were found to be the more slender in both characters. Equally anomalous are the facts relating to the antennal characters. A rigid selection is indicated in that the perfect ones have much shorter antennae, and as these are about the same in width in the two groups, a strong selection is shown in antenna proportions, the stouter organs being characteristic of the perfect pupae.

TABLE VIII.

Pupal-Imaginal Period. Selection in Type. Females.

Character	Mean. Survivors, Perfect	Mean. Survivors, Imperfect	(δ) Difference	(ϵ) Error of Difference	Proportion of $\delta : \epsilon$	Selection
Length	30·0595 ± ·1087	30·4239 ± ·0727	−0·3644	0·1307	$> 2\epsilon$	Probable
Weight	2·8571 ± ·0257	2·9173 ± ·0223	−0·0602	0·0340	$> 1\epsilon$	Possible {almost probable
Bust, Length	19·3309 ± ·0563	19·6620 ± ·0440	−0·3311	0·0714	$> 4\epsilon$	Certain
„ Width	12·5750 ± ·0432	12·6131 ± ·0347	−0·0381	0·0576	$< \epsilon$	None
„ Depth	13·5691 ± ·0437	13·6294 ± ·0373	−0·0603	0·0745	$< \epsilon$	None
„ Frontal Proportions	64·8690 ± ·1380	64·3044 ± ·1296	+0·5646	0·1892	$> 2\epsilon$	Probable {almost certain
„ Sagittal „	70·0952 ± ·1351	69·4783 ± ·1239	+0·6169	0·1833	$> 3\epsilon$	Certain
Left Antenna, Length ...	11·5500 ± ·0362	11·7271 ± ·0305	−0·1771	0·0474	$> 3\epsilon$	Certain
„ „ Width ...	4·3143 ± ·0152	4·3218 ± ·0151	−0·0075	0·0214	$< \epsilon$	None
„ „ Proportions	37·4631 ± ·1511	36·8152 ± ·1114	+0·6479	0·1877	$> 3\epsilon$	Certain

TABLE IX.

Pupal-Imaginal Period. Selection in Variability. Females.

Character	Standard Deviation. Survivors, Perfect	Standard Deviation. Survivors, Imperfect	(δ) Difference	(ϵ) Error of Difference	Proportion of $\delta : \epsilon$	Selection
Length	1·4748 ± ·0714	1·0345 ± ·0514	+0·4403	0·0879	$> 5\epsilon$	Reversed
Weight	0·3499 ± ·0182	0·3178 ± ·0158	+0·0321	0·0241	$> 1\epsilon$	Reversed
Bust, Length	0·7641 ± ·0397	0·6265 ± ·0311	+0·1376	0·0504	$> 2\epsilon$	Reversed
„ Width	0·5869 ± ·0305	0·5086 ± ·0252	+0·0783	0·0395	$> 1\epsilon$	Reversed
„ Depth	0·5933 ± ·0308	0·5317 ± ·0264	+0·0616	0·0407	$> 1\epsilon$	Reversed
„ Frontal Proportions	1·8721 ± ·0974	1·8429 ± ·0916	+0·0292	0·1337	$< \epsilon$	None
„ Sagittal „	1·8330 ± ·0953	1·7630 ± ·0876	+0·0700	0·1294	$< \epsilon$	None
Left Antenna, Length ...	0·4919 ± ·0256	0·4339 ± ·0215	+0·0580	0·0334	$> 1\epsilon$	Reversed
„ „ Width ...	0·2070 ± ·0107	0·2149 ± ·0106	−0·0079	0·0150	$> 1\epsilon$	Possible
„ „ Proportions	2·0498 ± ·1066	1·5844 ± ·0788	+0·4654	0·1325	$> 3\epsilon$	Reversed

Furthermore reversal of selection with respect to variability appears in some cases with astounding clearness. The perfect survivors are *certainly* more variable in total length, *probably* so in bust length, *possibly* in weight, bust width and bust depth. No significance attaches to the differences in bust proportions. While they are *possibly* more variable in antennal length, and *possibly* less variable in antennal width, the perfect survivors are *certainly* more variable in antennal proportions.

These results stand in the sharpest contrast to those referring to pupal elimination. As the proportionate characters of the bust are involved no less than the absolute values it must be concluded, I think, that the process of pupal-imaginal elimination involves certain factors which do not operate during pupal existence. Hence individuals which could and did survive the conditions of purely *pupal* existence find themselves marked for destruction by the very characteristics which formerly proved advantageous. I regard the reversal on the basis of variability as indicating the same conclusion also. Although discussion of these points may properly be deferred, it may be stated here that the enquiry into the actual basis of the selective processes may lead to a clearer understanding of the apparently conflicting facts.

V. *The Comparative Variability of Males and Females.*

The question as to which sex is the more variable is of considerable interest in some connections. It is not directly related, however, to the problem which is treated in the present paper, so that the facts may be presented in a brief form without any discussion at this time.

It is clear that it is not possible to determine the relative variability of the two sexes by a simple comparison of the indices of variation for any given character, for with a greater absolute value of any measurement a higher degree of variability is usually associated. A more satisfactory basis for comparison is afforded by the Coefficient of Variation, which is found by dividing the index of variability for any character by the mean value of that character. In order to obtain a convenient whole number, this quotient is generally multiplied by 100. By this means a measure of variability is derived which is independent of the absolute values concerned, though certain mathematical defects, which need not be considered here, may attach to this process.

In the subjoined table (Table X.) are given the coefficients of variability of the ten characters of both sexes, for the whole group (eight characters), for the surviving pupae, and for those which metamorphose perfectly. It will be seen that when the whole group is considered, the males are on the whole more variable than the females, the latter being more variable only in two of the bust measures. Among surviving pupae the male sex is far more variable, being less so in antennal proportions solely. And finally the same sex is the more variable on the whole as regards the body in the third group of perfectly metamorphosing pupae; for although the females are more variable in the absolute bust measures of length and depth, the other sex is more variable in the significant proportions of the bust. The lower value of the coefficients relating to the antennal characters of the males is extremely suggestive, I think, in view of the function which these organs perform during *imaginal* existence. It is now well known, owing particularly to the recent work of A. G. Mayer, that the male moth is guided by its sensory antennary organs in finding the female. It is decidedly interesting to find these organs are less variable in the sex for which they are the more useful.

TABLE X.

The Coefficients of Variability of Male and Female Pupal Characters.

Character	All.		Survivors.		Perfect Survivors.	
	Males	Females	Males	Females	Males	Females
Length	——	——	*4·38*	4·20	4·45	*4·90*
Weight	——	——	*12·43*	11·59	*14·65*	12·21
Bust, Length	4·21	*4·23*	*4·25*	3·66	3·83	*3·95*
„ Width	*5·14*	4·92	*5·07*	4·35	*5·03*	4·66
„ Depth	4·46	*4·57*	*4·34*	4·12	4·16	*4·37*
„ Frontal Proportions	*4·12*	3·61	*3·79*	2·90	*3·69*	2·88
„ Sagittal „	*3·16*	2·86	*3·14*	2·61	*3·00*	2·61
Left Antenna, Length ...	*4·91*	4·90	*4·12*	4·09	3·84	*4·25*
„ „ Width ...	*5·95*	5·43	*5·15*	4·66	4·63	*4·80*
„ „ Proportions	*5·26*	5·20	4·93	*5·30*	4·80	*5·47*

VI. *Discussion and Conclusion.*

The facts recorded in the foregoing account relate to eight or to ten characters of the pupae of one species of Saturnid moth for one winter season. It is obvious that it would be futile to discuss the bearing of these facts upon the wide question of evolution in any extended form, until the figures here given may be supplemented by others relating to the same and other species of moths, obtained by more detailed studies upon the same and related questions in more abundant material. It is nevertheless necessary to deal briefly with certain aspects of the evidence which has been offered, in order to avoid misconception regarding the main conclusion stated, namely, that there is a real relation between the process of elimination in pupae, and the extent and character of their variation. It may be stated here, that the results of later studies have in no essential way altered the point of view which was arrived at from the consideration of the results of the initial investigation, here recorded.

But before we may examine more closely into the manifestation of selection in the present case, certain possibilities of error demand frank recognition. (1) The number of individuals is smaller than is desirable for the purposes of statistical treatment. It is clear that this error has been allowed for, in so far as each comparison has been based upon the numerical values of the types or of the variabilities *together with their probable errors,* and these are determined by formulae which take full account of the number of cases under investigation; and besides, the occurrence of selection has been asserted only when the difference between comparable indices of variation or between two typical values is in excess of thrice the probable error, certainly a generous allowance. (2) In dealing with graduated values like the various dimensions of the pupa there must always be an error due to the "personal coefficient." Enough individuals have been used to render this error negligible, for according to the law of probability the errors in excess will be offset by errors in underestimation. (3) A far more important objection may be urged against the comparison of the surviving pupae with those which were dead when found; and of course the value of the comparison which has been drawn in the present study cannot be considered as final until definite data are obtained showing the effect that death exerts upon the pupal characters under examination. But the objection can be urged only in certain cases, for the rigid nature of some of the pupal structures, like the antenna, is such that little or no alteration can follow death*; and furthermore it does not militate against the treatment of pupal-imaginal elimination, for all the individuals there considered were alive both at the time of measurement and at the time of metamorphosis. (4) Attention has already been directed to the fact that some of the dimensions used are only approximations, as the length and proportions of the antenna; the former is really the chord of the arc described by the axis of this organ. But it is legitimate to suppose that all chords of a given length represent arcs of the same value on the whole, as those arcs with greater curvature will be offset by arcs with less curvature, and that therefore a chord of a certain value will correspond to a certain average value of the arc. At any rate the differences between comparable determinations of antennal characters in the several groups may be regarded as indicating real differences in antennal structure.

And now, turning to the fundamental question of selection, we must recognize clearly at the outset the essential fact that *elimination does occur* during pupal existence and as well at the time of metamorphosis. Those individuals which reach the end of pupal existence form but a portion of the whole number entering it, and those animals which reach perfect maturity form again a subdivision of the previous group. The fact of reduction in numbers stands unquestioned.

We have seen that those individuals which successfully survive the severe conditions of pupal existence or of metamorphosis are structurally different in some respects from those which do not, and that the former are on the whole less variable. Consequently we are justified in concluding that elimination proceeds upon a selective basis; for although we must admit that *some* of the eliminated, killed by "chance," may have been just as "fit" as the survivors, yet it is not possible that *all* of them were. Certainly, all of the survivors were "fit." Wherefore the observed differences between any two comparable measurements of the two groups afford tangible determinations of the instability of organization with which unfitness is associated. Natural selection is thus found to exist in the material under consideration. Two questions, however, immediately arise: How far is the process natural? and: In what respects is it selection?

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* I have remeasured dead pupae after a two years' interval and have indeed found certain minor differences between the original measurement and the later one. In no case, however, of 70 recently remeasured has the difference led to a change of class of the individuals.

The conditions for pupal elimination were certainly natural in every respect, and it is equally certain that the circumstances attending pupal-imaginal elimination were not the same as those which the pupa meets in nature at the time of metamorphosis. For the pupae in the second case were kept in a cabinet in the laboratory for some weeks and were subjected to warmer and drier air than usual. And yet elimination and selection appear at the second period no less clearly than during pupal existence. As regards the relation which secondary selection bears to primary elimination, we have seen that the two sexes differ in an interesting way. In the male sex the direction taken by selection is the same in both cases. Therefore we may conclude, if the figures relating to the first period be accredited, that the selective agencies were the same during both periods; or to put the matter in another way, we may say that the same physical characteristics of the pupae were tested in the two periods. But in the female sex it was found that, on the whole, secondary selection took place in the reverse direction, and we must conclude either that the conditions which exercise a restrictive effect at the time of metamorphosis are different from those which operate earlier, that in other words the organic test refers to other pupal functions, or else that the unnatural conditions of the laboratory produce a different result from that which would have occurred in nature. The facts are so different in the two sexes, that a direct investigation of this important problem should, and will, be made. Nevertheless, the *fact of primary importance is, not that selection is here natural in the sense that it would have occurred in nature, but that the reduction in numbers proceeds hand in hand with a restriction in certain structural characteristics as regards type and variability.*

The next point to be noted is, that *selection, where it occurs, cannot be based directly upon the characters of the pupa which we have described as showing selection.* The pupa does not "use" its antennae, and no conceivable advantage can accrue to the pupa from a longer, wider, and stouter organ, and yet the survivors have on the whole longer, wider, and stouter antennae. Again, it is difficult to conceive how particular dimensions of the bust can serve advantageously or disadvantageously in the struggle for existence during the pupal period. What, then, is the actual basis for eliminative selection?

We approach the true solution of the problem, I believe, when we realize that we are justified in stating nothing more than that the surviving pupae or those which metamorphose perfectly are of particular forms, and are more conservative with reference to those particular forms than are the individuals which succumb. In short, we may not say that the longer antennae serve the pupa in escaping elimination, but we are justified only in asserting that the surviving pupae have longer antennae. When this statement is made for all the characters which exhibit selection, we see that the essence of fitness is a morphological conservatism with reference to certain values of the dimensions under consideration. Certain it is that those which depart widely from the "fit" type are numbered among the dead.

According to this view, elimination is based upon the general or total efficiency of any individual. And this value is determined by the proper coordination of functional and structural elements. The actual basis for elimination is, in a word, correlation. If this be slight, a condition of less stable equilibrium arises which renders the particular individual less efficient, and which places it among the unfit. In the present case, however, we are dealing with an organism, the pupa, which does not use its structures; so that any lack of proper correlation is attributable to an absence of proper coordination among the formative factors which control the establishment of pupal structures, or by which the imago is constructed upon the pupal basis.

I believe, then, that the test of fitness or unfitness has reference to the physiological and morphological coordination or correlation among the constituent elements of the whole organism, and that any relaxation in either series, in a formative sense or otherwise, results in an instability which may culminate in death and which expresses itself in structural deviation as well as in a higher degree of variability.

BARNARD COLLEGE, COLUMBIA UNIVERSITY,
November, 1903.

ON THE LAWS OF INHERITANCE IN MAN.

II. ON THE INHERITANCE OF THE MENTAL AND MORAL CHARACTERS IN MAN, AND ITS COMPARISON WITH THE INHERITANCE OF THE PHYSICAL CHARACTERS*.

By KARL PEARSON, F.R.S.

(i) *Introductory.—The Material and its Collection.*

THERE are probably few persons who would now deny the immense importance of ancestry in the case of any domestic animal. The stud-books, which exist for horses, cattle, dogs, cats and even canaries, demonstrate the weight practically given to ancestry when the breeding of animals has developed so far that certain physical characters possess commercial value. A majority of the community would probably also admit to-day that the physical characters of man are inherited with practically the same intensity as the like characters in cattle and horses. But few, however, of the majority who accept this inheritance of physique in man, apply the results which flow from such acceptance to their own conduct in life—still less do they appreciate the all important bearing of these results upon national life and social habits. Nor is the reason for this—or better, one out of several reasons for this—hard to find. The majority of mankind are more or less conscious that man has not gained his pre-eminence by physique alone. They justly attribute much of his dominance in the animal kingdom to those mental and moral characters, which have rendered him capable of combining with his neighbours to form stable societies with highly differentiated tasks and circumscribed duties for their individual members.

Within such communities we see the moral characters developing apparently under family influences; the mental characters developing not only under home training, but under the guidance of private and public teachers, the whole contributing to form a complex system of national education. To use technical terms, we expect correlation between home influence and moral qualities, and between education and mental power, and the bulk of men too rashly, perhaps, conclude that the home and the school are the chief sources of those qualities on which social stability so largely depends. We are too apt to overlook the possibility that the home standard is itself a product of parental stock, and that the relative gain from education depends to a surprising degree on the raw material presented to the educator. We are agreed that good homes and good schools are essential to national prosperity. But does not the good home depend upon the percentage of innately wise parents, and the good school depend quite as much on the children's capacity, as on its staff and equipment?

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* Being the Fourth Annual Huxley Lecture before the Anthropological Institute, reprinted with the sanction of the Council.

It is quite possible to accept these views and yet believe that the moral and mental characters are inherited in either a quantitatively or a qualitatively different manner from the physical characters. Both may be influenced by environment, but the one in a far more marked way than the other. Since the publication of Francis Galton's epoch-making books, *Hereditary Genius* and *English Men of Science,* it is impossible to deny *in toto* the inheritance of mental characters. But we require to go a stage further and ask for an exact quantitative measure of the inheritance of such characters and a comparison of such measure with its value for the physical characters.

Accordingly some six or seven years ago I set myself the following problem: What is the quantitative measure of the inheritance of the moral and mental characters in man, and how is it related to the corresponding measure of the inheritance of the physical characters?

The problem really resolved itself into three separate investigations:—

(*a*) A sufficiently wide inquiry into the actual values of inheritance of the physical characters in man.

This investigation was carried out by the measurement of upwards of 1000 families. We thus obtained ample means of determining both for parental and fraternal relationships the quantitative measure of resemblance.

(*b*) A comparison of the inheritance of the physical characters in man with that of the physical characters in other forms of life.

This has been made for a considerable number of characters in diverse species, with the general result that there appears to be no substantial difference, as far as we have been able to discover, between the inheritance of physique in man, and its inheritance in other forms of life.

(*c*) An inquiry into the inheritance of the moral and mental characters in man.

This is the part of my work with which we are at present chiefly concerned, and I want to indicate the general lines along which my argument runs.

In the first place it seemed to me absolutely impossible to get a quantitative measure of the resemblance in moral and mental characters between parent and offspring. You must not compare the moral character of a child with those of its adult parents. You can only estimate the resemblance between the child and what its parents were as *children*. Here the grandparent is the only available source of information; but not only does age affect clearness of memory and judgment, the partiality of the relative is a factor which can hardly be corrected and allowed for. If we take, on the other hand, parents and offspring as adults, it is difficult to appeal to anything but the *vox populi* for an estimate of their relative moral merits, and this *vox* is generally silent unless both are men of marked public importance. For these and other reasons I gave up any hope of measuring parental resemblance in moral character. I confined my attention entirely to *fraternal* resemblance. My argument was of this kind. Regarding one species only, then if fraternal resemblance for the moral and mental characters be less than, equal to, or greater than fraternal resemblance for the physical characters, we may surely argue that parental inheritance for the former set of characters is less than, equal to, or greater than that for the latter set of characters.

In the next place it seemed impossible to obtain moderately impartial estimates of the moral and mental characters of *adults*. Who but relatives and close friends know them well enough to form such an estimate, and which of us will put upon paper, for the use of strangers, a true account of the temper, probity and popularity of our nearest? Even if relatives and friends could be trusted to be impartial, the discovery of the preparation of schedules by the subjects of observation might have ruptured the peace of households and broken down life-long friendships. Thousands of schedules could not be filled up in this manner. The inquiry, therefore, resolved itself into an investigation of the moral and mental characters of *children*. Here we could replace the partial parent or relative by the fairly impartial school teacher. A man or woman who deals yearly with forty to a hundred new children, rapidly forms moderately accurate classifications, and it was to this source of information that I determined to appeal.

I would refer at once to an objection, which I think is not real, but which I know will arise in the minds of some. It will be said that the temper, vivacity and probity of children is not a measure of the like qualities in the adult. The shy boy at school is not necessarily a shy man on the floor of the House of Commons or confronting a native race on the north-west frontier. Granted absolutely. But what we are comparing is what that boy was at school, with what his brother and sister may have been. We can legitimately compare for purposes of heredity a character of the larval stage of two insects, although that character disappears entirely when both are fully developed as *imago*.

It is possible that some allowance ought to be made for changes during the school period in the mental and moral characters, but I have not found that those characters change very substantially in their percentages with the age of the school children, the bulk of whom lie between 10 and 14. Accordingly, while the physical characters change during the school period, it did not to a first approximation seem needful to allow for age changes in the mental and moral characters*. Such changes may exist, but they do not appear to be so marked as to substantially influence our results.

In order to carry out this investigation I sought and received aid from the Government Grant Committee of the Royal Society. I have further to acknowledge the assistance I have received, in the task of reduction and computation, from a grant made to my department at University College, by the Worshipful Company of Drapers.

I had deemed it desirable to measure not only the mental and moral characters, but a wide range of physical characters also. These would act as a check on the whole work, for we knew perfectly well what the inheritance of these physical characters might be expected to be. They were further needed as part of a more general investigation into the relationship between the mental and physical characters in man. In order to confine the cost of the inquiry within reasonable bounds, a special head-spanner was devised with the assistance of Mr Horace Darwin of the Cambridge Scientific Instrument Company. This instrument has not the exactness, of course, of the metal callipers of the craniologists, but it affords, carefully handled, a quite adequate means of obtaining the maximum length, maximum breadth and auricular height of the living head. It had further the great advantage that, made in numbers, it cost comparatively little and could be distributed widely among teachers.

Schedules were then, after much consideration and some experimenting, prepared, in which teachers could briefly note the chief characteristics of the children under their charge. These schedules were white for a pair of brothers, pink for a pair of sisters, and blue for a brother and sister. Additional brothers were given on attached white, and additional sisters on attached pink sheets. With the schedules were distributed (*a*) printed directions for the use of the head-spanner; (*b*) general directions as to the estimation of both the physical and mental characters; and (*c*) two additional series of lithographed instructions, which were suggested by special inquiries of the teachers who first began the observations. Copies of the schedule and the general directions are printed in Appendix I.

The material took upwards of five years to collect. Appeal was made through the columns of the educational journals to teachers of all kinds, and our observations were made not only in the great boys' public schools, in the girls' high schools and the grammar schools of the country, but in modern mixed schools, in national and elementary schools of all kinds, in board schools and private schools throughout the kingdom. Some 6000 schedules were distributed and between 3000 and 4000 returned with more or less ample data. I have most heartily to thank the masters and mistresses of nearly 200 schools in which observations have been made for me. In the midst of arduous professional claims on their time and energy, they have, in many cases at considerable personal inconvenience, recorded and measured the children in their charge, for a purpose only dimly foreshadowed to them. In no case could they realise on the basis of their own 10 or 20 schedules the value of the scientific inquiry to which they were contributing, for its success depended entirely on the combination of tens and twenties into hundreds and thousands, a possibility which even some of my keenest assistants despaired of during the years in which the investigation was in progress. We were, indeed, more than once confronted by an apparent drying up of all conceivable sources of new material. The number of schools is of course immense, but the means of reaching and interesting their masters and mistresses extremely limited*. It is only right and proper to place on record the names of my chief co-operators in this investigation. See Appendix II.

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* An additional memoir on the change of mental and physical characters with growth is in course of preparation.

The list in Appendix II. will not only show the class and range of the schools dealt with, but also the great variety of localities which contributed. As far as the United Kingdom contains local races, we have fairly sampled them. Of course one would much prefer to have dealt entirely with a single district with little immigration, and thus have worked wholly within one local race, but a little consideration showed how impossible it was to get material enough for any safe conclusions from such a limited area. It is not one per cent. of teachers who can spare the time, or, being able to spare the time, have the imagination which will induce them to aid in co-operative inquiry of this kind. With the assistance of Mr E. W. Adair an attempt at a limited area was made in the case of Guernsey. But we only succeeded in getting 150 to 200 schedules filled in. These were sufficient to show that a perceptible differentiation in the physical characters existed between Channel Island and English children. No differentiation in the psychical characters could be observed. Accordingly the Guernsey children were not pooled with the others for physical characters, but the material was far too insignificant in amount to justify a separate investigation of the statistical constants†. The influence of local race would undoubtedly make itself felt on our statistics, but taken broadly our constants represent the condition of things in the nation at large, and if any portion of the relationship between brothers and sisters is really due to local race, then we must inquire whether local race is or is not equally influential on the moral and mental characters. My belief that local race is not largely influential in this enquiry is based fundamentally on the following facts:—

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* I must not omit to acknowledge the courtesy of the editors of the *Journal of Education*, *The School World*, *The Schoolmaster* and other educational journals in publishing my appeals.

† While showing a certain differentiation, the general accord between the Guernsey correlations and those of the United Kingdom was remarkable, and extremely satisfactory when we want confirmation of the fact that, within broad lines, we are dealing with general "human" characters and relations, and not with something peculiar to "local race." As an instance I cite the "correlation ratio," η, a constant determining association,—for the case of head growth with age in girls. Guernsey Girls: $\eta = \cdot 44$; English Girls: $\eta = \cdot 46$. Considering that this Guernsey result is based on 110 cases only, the agreement is remarkable. We are clearly dealing with a constant of human growth in general.

(*a*) The constants of parental heredity deduced from my Family Records, made like the School Observations on members of many English local races, are closely like results found for such selected breeds as race-horses and greyhounds.

(*b*) The Family Records and the School Observations are for the fraternal relationships in excellent agreement.

Hence, while I admit the "local race" problem to be of first-class importance for many anthropological investigations, I do not think that to a *first* approximation, it has had sensible bearing on our present results.

So much may be said here about the nature and manner of collecting our material. The absolute classification and tabling has been a work of great labour. I have to thank in this matter my group of co-workers at University College, more especially Miss Alice Lee, D.Sc.; Miss Marie Lewenz, M.A., Miss E. Perrin, Miss Mary Beeton and Miss Margaret Notcutt have likewise aided me. More recently in the pressure of preparation for this lecture Mrs W. F. R. Weldon and Miss F. E. Cave have come strenuously to my assistance. The chief labour of computing has fallen upon Dr Alice Lee, but a considerable number of the tables have been re-done or revised by myself. Miss F. E. Cave has either computed, or re-worked and computed, a considerable number of the head measurements and growth with age tables (not here published) necessary for the reduction of head measurements to a uniform age. To Miss M. Lewenz I owe aid in the computation of the health, ability and athletics data. In short, although *I* may be giving the Huxley Lecture, the work is essentially the result of a co-operative investigation extending over a number of years, and depending upon a body of collaborators, without whom it would have been quite impossible to deal with, much less to collect, the extensive data on which my results entirely depend.

(ii) *Nature of the Theory Applied.*

Much of what I have to say upon this point would not be new to those who have examined recent biometric work, and some of it would not be intelligible except to the trained mathematician. Still we must strive in broad lines to see how the work has been done, and above all, to justify our treatment of the psychical characters.

To illustrate the method I will examine a little at length the degree of resemblance of brothers in a physical character. I choose cephalic index and this for two reasons:—

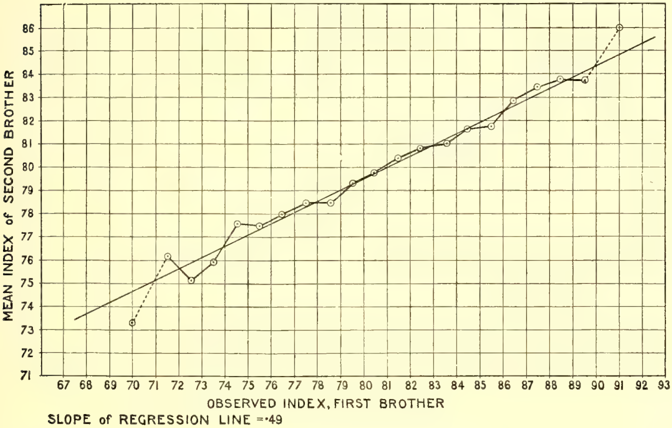
(*a*) Because from the first few years of life onwards the cephalic index scarcely changes with growth.

I have not yet investigated my own school data from this standpoint, but I have every confidence in the care taken by the late Dr W. Pfitzner in his elaborate system of measurements, and the above is the conclusion he reaches*.

(*b*) Several great authorities have recently stated that they do not "believe" in the cephalic index, i.e., consider it of small value for anthropometric purposes.

In Table E (i), Appendix III., we have the cephalic index given for 1982 pairs of brothers. This table is, I hope, perfectly intelligible. Taking the boys, for example, with cephalic indices between 74 and 75, these boys had 78 brothers who were distributed according to the arrangement in the column headed 74 to 75. Brothers are not alike in cephalic index, but distributed with a considerable range of variation. We now take in the usual way the arithmetic mean of this array of brothers, and find it to be 77·45. The average brother of a boy with cephalic index = 74·5 has an index of 77·45. This is the phenomenon of regression towards the general population mean (78·9) as discovered by Francis Galton. Now turning to Diagram I. we plot to 74·5, the mean brother 77·45, and doing this for all arrays we get the series of points there exhibited. You will see at once that they lie almost exactly on a straight line. This is the well-known regression line. If

DIAGRAM I. *Resemblance of Brothers in Cephalic Index.*



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* *Zeitschrift für Morphologie u. Anthropologie*, Vol. I. 1899, p. 372. My schoolboys from all districts give 78·9; 3000 criminals of adult age from all districts give 78·5—there is not much room for sensible growth change in these juvenile and adult results. Observations of my own on actually the same growing children, show very small, if any change.

Diagram II. *Resemblance of Sister's Span to Brother's Forearm.*

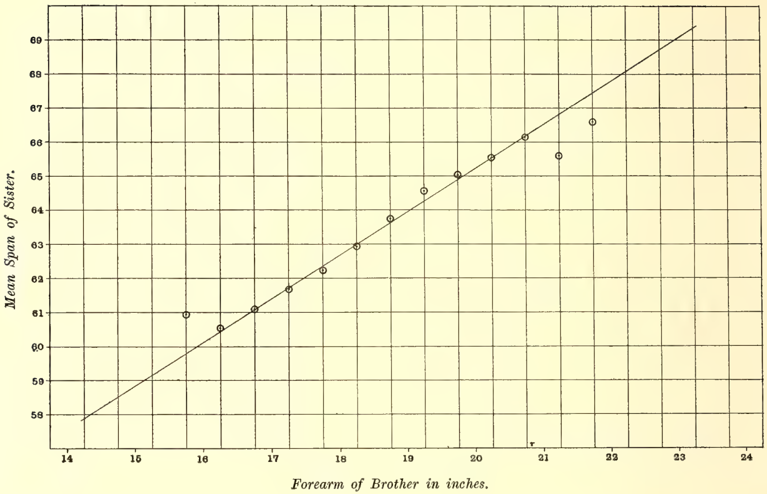
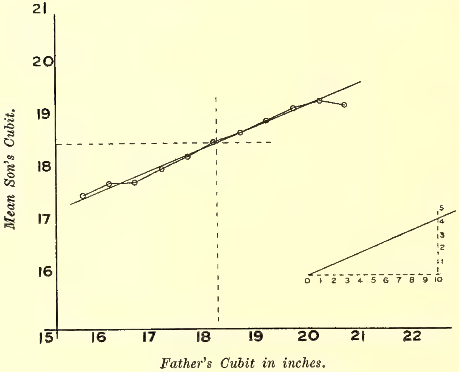


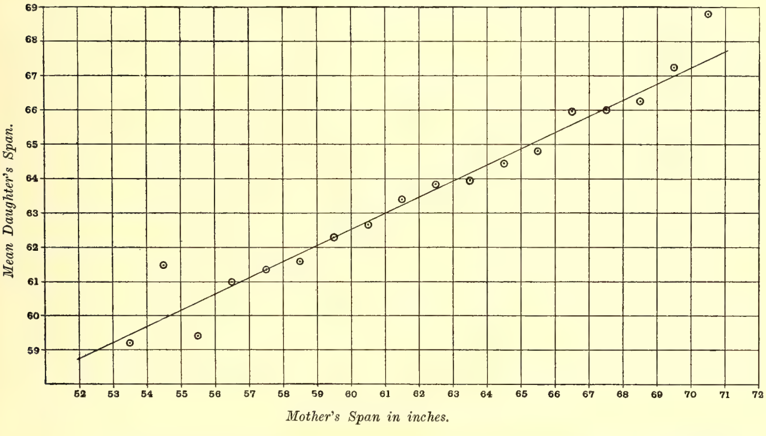
Diagram III. *Resemblance of Father and Son in Cubit.*



that line had a slope of 1 in 1, the brother of 74·5 would have a mean brother of 74·5 cephalic index. If it had no slope at all the brother of 74·5 would have a brother like the mean of the general population. In the one case we have absolute resemblance, in the other case no resemblance at all. The actual degree of resemblance, our brothers being equally variable, is measured by the steepness of this regression line. In our case that steepness is ·49, almost ·5 or 1 in 2. That is the measure of fraternal resemblance in brothers for cephalic index—the correlation between brothers as we term it.

Now we have learnt two great features of inheritance in man. First, that the points in Diagram I., within the limits of observation, are on a line, and secondly, that the slope of this line is about ·5. Are these results true for characters other than the cephalic index? Undoubtedly for all the physical characters yet worked out in man. Here are additional illustrations: see Diagrams II.—IV.* We cannot hesitate about the regression line being essentially linear. Has it for brethren usually a slope of about ·5?

DIAGRAM IV. *Resemblance of Mother and Daughter in Span.*



In Table I. are given my observations on some 1000 families for adult brothers and sisters. You will see that the steepness of the regression line is essentially about ·5.

In Table II. are given my observations on the head measurements of school children. We note at once precisely the same convenient number ·5.

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* Diagrams II. and IV. are reproduced from the memoir by the author on "Inheritance of the Physical Characters in Man," *Biometrika*, Vol. II. pp. 362–3, and Diagram III. from an article in the same journal, Vol. II. p. 216, on the "Law of Ancestral Heredity."

I think we, therefore, may safely conclude that for the measurable physical characters in man, we have a quite definite regression line, and that it ascends 1 in 2.

TABLE I.

Inheritance of the Physical Characters.

Records of Adults.

Character.	Correlation.		
	Brothers.	Sisters.	Brothers and Sisters.
Stature...	·51	·54	·55
Span	·55	·56	·53
Cubit	·49	·51	·44
Eye Colour	·52	·45	·46
Mean	·52	·51	·49

TABLE II.

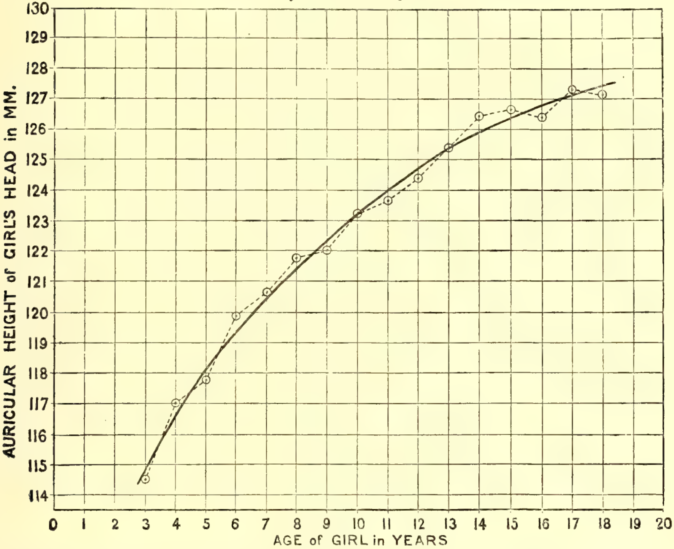
Head Measurements on School Children.

Pair→	Brother-Brother.			Sister-Sister.			Brother-Sister.				
Characters.	Mean.	S.D.	Correlation.	Mean.	S.D.	Correlation.	Mean.		S.D.		Correlation.
							B.	S.	B.	S.	
Cephalic Index..	78·92	3·314	·4861	78·29	3·988	·5360	78·72	78·96	3·237	3·382	·4265
Head Length (12 years)	184·52	6·454	·5041	180·22	6·346	·4251	183·82	179·20	6·563	6·510	·4575
Head Breadth (12 years)	145·23	5·739	·5925	140·21	6·547	·6208	144·24	140·59	5·975	5·708	·5419
Head Height (12 years)	127·19	6·479	·5537	124·07	6·868	·5237	127·36	124·80	7·031	6·226	·4897
Mean.	—	—	·5341	—	—	·5264	—	—	—	—	·4789

S.D. = Standard deviation, the measure of the variability of the observed character.

It is proper before I go further, to explain how the results for resemblance between brothers and sisters of different ages in head measurements have been made. In the first place a growth curve for each sex and for every measurement was drawn; this growth curve simply consists in plotting the average size of head of a child of given age to that age. Diagram V. represents the growth of auricular height of head of the mean girl from 4 to 19 years of age. The observation points are then smoothed and we obtain the mean growth curve. I cannot stay to discuss these mean growth curves now, but it must be clear that they give us a method of ascertaining the mean head growth of a child from any one year of its life to any other. Now all children do not grow in the same manner, but as we are dealing with average results we shall obtain a reasonable measure of growth by using the growth curve of the mean child. By means of six growth curves like that shown, the length, breadth, and height of every child's head was reduced to the dimensions it would most probably have at the age of 12 years. Thus we were able to compare the likeness in head measurements of brothers at the *same* standard age. This is the method by which the inheritance of head length, breadth, and height, given in Table II., was deduced*.

Diagram V. *Growth of Auricular Height in Girl's Head.*



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* By a much more elaborate investigation in multiple correlation I found for resemblance between brothers in head length ·54 (see *R. S. Proc.* Vol. 71, p. 294). The growth correlation not being absolutely linear, I am not sure that that value is better than the ·5 of the present simpler method.

Now what are we to understand by "believing" or "not believing" in the value for anthropological purposes of any character? Surely the main point for such purposes is the question of whether or no it be inherited and have small variability within the group? I don't think if we look at Table II. we shall find the cephalic index worse than other head measurements, especially if we stick to one sex. It has an inheritance coefficient of about ·5, just what for practical purposes we have found for other physical characters.

So far we have seen surprising uniformity in the inheritance of the measurable physical characters. How are we to extend our results to physical characters not capable of accurate measurement, and to psychical characters? Clearly the whole problem turns on this: Can we find the steepness or slope of this regression line without all the paraphernalia of the correlation table and the means of arrays? The answer is: Yes; providing we assume a certain distribution of frequency for the character in human populations. This distribution of frequency is given by the Gauss-Laplacian normal curve of deviations from the mean. Grant this distribution, and by very simple classifications indeed we can determine the steepness of the regression line. Now the problem before us is the following one:—Is this assumption legitimate? It is certainly not true for organs and characters in *all* types of life. But it really does describe in a remarkable manner the distribution of most characters in mankind. We have shown that within the limits of random sampling, it is very true for a great variety of characters in the human skull*. Dr Macdonell has demonstrated it also for measurements on criminals, and you can be fairly convinced of its suitability by looking at one or two diagrams. Diagram VI. gives the distribution of nearly 2000 boys in cephalic

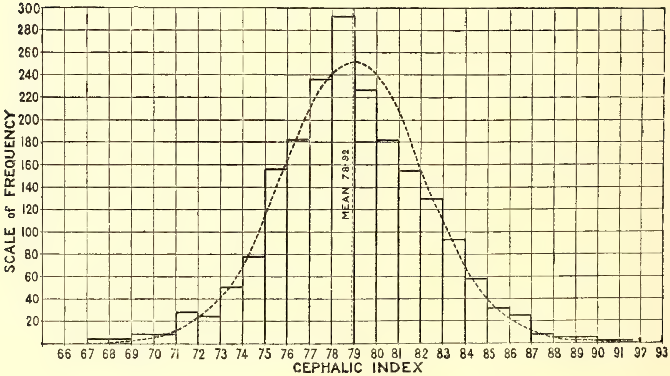
DIAGRAM VI. *Distribution of Cephalic Index in* 1982 *Boys.*

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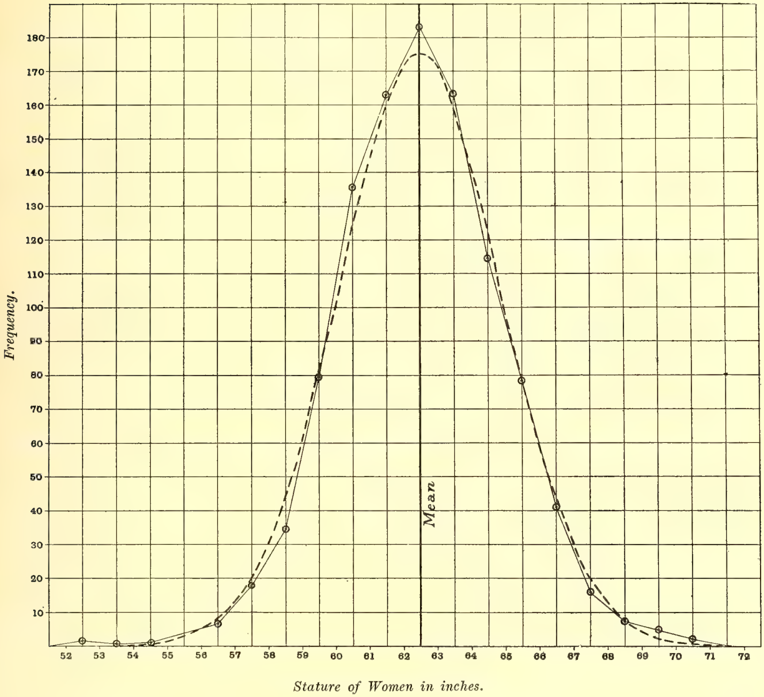
* *Biometrika*, Vol. I. p. 443.

index; Diagram VII. the distribution of stature in 1000 women; Diagram VIII. the distribution of head breadth in 3000 criminals*. I should be the last to assert that no human characters can be found that do not diverge sensibly from this Gaussian distribution. But I believe they are few, and that for practical purposes we may with nearly absolute safety assume it as a first approximation to the actual state of affairs. This being once granted we can obtain the slope of our regression line by an exceedingly simple process. We can make a mere classification of the following kind, say, into boys with breadth of head below 145 mm.,

DIAGRAM VII. *Distribution of Stature in Women.*



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* Diagram VII. is from the paper on the "Inheritance of the Physical Characters in Man," *Biometrika*, Vol. II. p. 364, and Diagram VIII. from Dr Macdonell's memoir in this journal, Vol. I. p. 184.

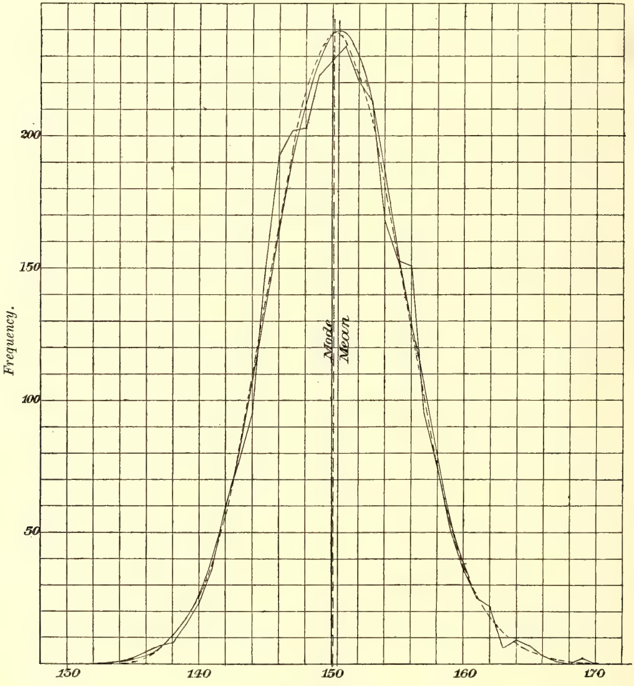
and boys with breadth of head above 145 mm. For example, here is a simple classification of 2022 pairs of brothers by this process:—

Breadth of Head.
First Brother.

Second Brother.	Below *145*	Above *145*	Totals
Below *145* ...	635·5	307	942·5
Above *145* ...	307	772·5	1079·5
Totals	942·5	1079·5	2022

The result is precisely the same as dividing this ring model (*exhibited at the lecture*) by a pair of rectangular planes and counting up the number of rings in each of the four spaces.

Diagram VIII. *Distribution of Head Breadths in* 3000 *Criminals.*



Normal curve given by continuous line.

Now from such a division the mathematician can deduce* the slope of the regression line on the assumption of normal distribution. Here, to give us confidence, are the results for head breadth and height in boys, which were worked out both ways:—

Resemblance of Brothers.

	Long table	Fourfold division
Head Breadth	·59	·58
Auricular Height ...	·55	·56

For practical purposes these results are identical.

Accordingly let us assume this fourfold division will work, and investigate by means of it a non-quantitatively measurable physical character in man. I choose *Health* as an example. In Table A (i), Appendix III., we have the distribution of health in a population of 1918 school boys, and in Diagram IX., we have the arrangement of the same material, supposing it to follow a normal curve. My five classes were (i) *Very Strong*; (ii) *Strong*, being here used not in the sense of physically strong, but of *Robust*; (iii) *Normally Healthy*; (iv) *Rather Delicate*; and (v) *Very Delicate*. You will see that the "modal" boy is somewhat on the normally healthy side of robust, but that the *Very Robusts* are more numerous than the *Very Delicates* and the *Robusts* than the *Delicates*. I think the scale is not without suggestiveness even as a general health distribution for the population at large. It gives us for the first time an exact measure of the ranges of delicacy and robustness in terms of normal health.

Now I applied this scale to the relation between brothers in health character. I plotted up at the mean of robust boys, a length on this scale equal to the mean on the same scale of the array of brothers of these robust boys; there was naturally a regression towards normal health. I did this for all the possible five arrays†, and I thus obtained the five points given in Diagram X. You will see at once that our five points lie quite nicely distributed about the regression line as found by the fourfold division method discussed above. In other words, there can be little doubt that the general health of boys is a character which closely follows the normal law of distribution, and has a true line of regression. The slope of that line is ·52, or we may safely say that general health in the community is inherited in precisely the same manner as head-measurements or body-lengths.

I now come to the fundamental idea of my comparison of the psychical and physical resemblance of brothers. Suppose we assume that moral and mental qualities in man, like the physical, follow a normal law of distribution, and that

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[*] Mathematical Contributions to the Theory of Evolution. VII. "On the Correlation of Characters not Quantitatively Measurable," *Phil. Trans.* Vol. 195, A, pp. 1—47.

[†] For the benefit of the mathematical statistician, I may say that I used the modal group of each sub-array to determine its mean and standard deviation in terms of those of the scale for the whole population.

Diagram IX. *Distribution of Health in* 1918 *School Boys.*

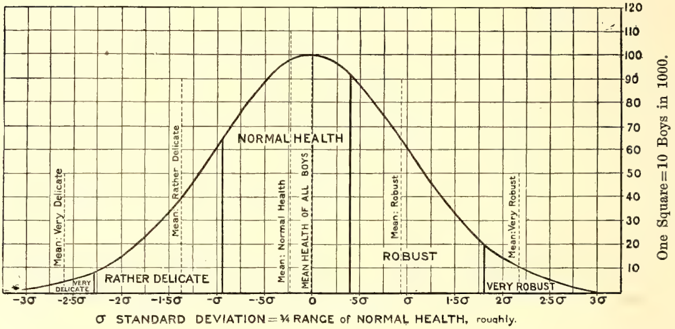
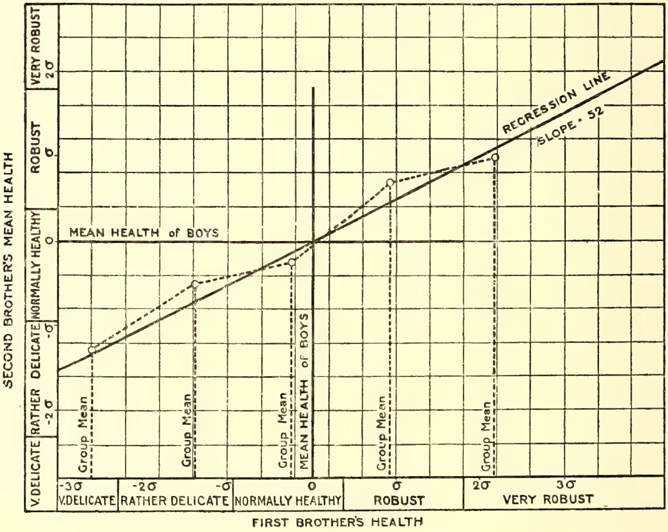


Diagram X. *Resemblance in General Health of* 1918 *Pairs of Brothers.*



the regression is linear. What results shall we obtain by thus assuming perfect continuity between the physical and the psychical? No doubt the drums will begin to beat the tattoo, we shall hear talk of the hopeless materialism of some men of science. But to use Huxley's appropriate words: "One does not battle with drummers." I cannot free myself from the conception that underlying every psychical state there is a physical state, and from that conception follows at once the conclusion that there must be a close association between the succession or the recurrence of certain psychical states, which is what we judge mental and moral characteristics by, and an underlying physical confirmation be it of brain or liver. Hence I put to myself the problem as follows:—Assume the fundamental laws of distribution which we know to hold for the physical characters in man, and see whither they lead us when applied to the psychical characteristics. They must: (*a*) Give us totally discordant results. If so, we shall conclude that these laws have no application to the mental and moral attributes. Or, (*b*) Give us accordant results. If so, we may go a stage further, and ask how these results compare with those for the inheritance of the physical characters: are they more or less or equally subject to the influence of environment? Here are the questions before us. Let us examine how they are to be answered. As an illustration I take *Ability in Girls.* I measured intelligence by the following seven classes. (i) *Quick Intelligent*; (ii) *Intelligent*; (iii) *Slow Intelligent*; (iv) *Slow*; (v) *Slow Dull*; (vi) *Very Dull*; and a quite distinct category (vii) *Inaccurate-Erratic.* Some explanation of these terms is given in Appendix IA., which contains the general instructions for observation, and the terms themselves were practically formulated by a schoolmaster of considerable pedagogic and psychological experience.

My next stage was to ask two or three different teachers in several schools to apply the classification to 30 to 50 pupils known to each of them. The classifications were made quite independently, often by teachers of quite different subjects, and a comparison of the results showed that 80 to 85 per cent. of the children were put into the same classes by the different teachers, while about 10 per cent. more only differed by one class. This gave one very great confidence not only in the value of this scale, but of other psychical classifications when used by observant teachers. The next stage was to obtain exactly, as in the case of *Health*, a general scale of intelligence*.

Diagram XI. gives the normal distribution of intelligence in a population of 2014 girls. It is a curious, if a common result of experience, to find that the modal ability is on the borderland between the *Intelligent* and *Slow Intelligent.* We have here for the first time a quantitative scale of intelligence, and we can at once apply it to the problem of the degree of resemblance between sisters as regards ability. Just as in the case of *Health*, all the girls of a given class are taken, say the *Slow Intelligents*, and at the average value of this class, is plotted upon this scale of intelligence, the average value of the intelligence of the sisters of these girls on

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* I should say at once that the *Inaccurate-Erratics* turned out a surprisingly small class, a fractional per cent. of the community, and that they were not further dealt with.

Diagram XI. *Distribution of Intelligence in 2014 Girls.*

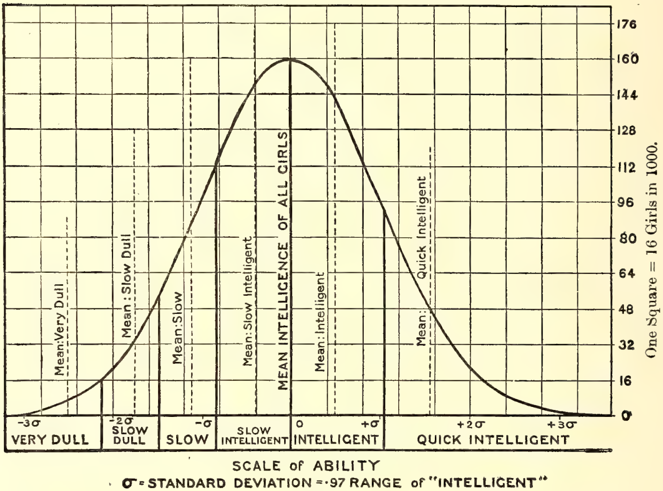
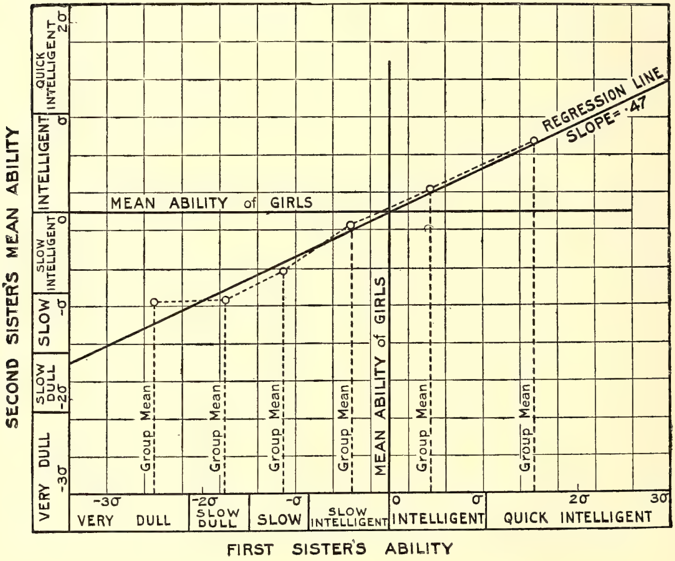


Diagram XII. *Resemblance of Sisters in Ability.*



the same scale. We thus obtain the six points of Diagram XII., all well within the limits of random sampling, lying on the straight line found from the fourfold division of the data. The slope of this line is ·47 or 47, close to 50, in the 100. There can, I think, be small doubt that *Intelligence* or *Ability* follows precisely the same laws of inheritance as *General Health*, and both the same laws as *Cephalic Index*, or any other physical character.

In precisely the manner indicated here all the other physical and psychical characters recorded may be dealt with. But before we sum up our results for the slopes of all the lines thus investigated, it is most essential to make, especially to an anthropological audience, some remarks on the manner in which the individual physical and mental characters have been treated.

(iii) *Remarks on Individual Characters dealt with.*

Physical Characters.

(A) *Health.*—We have already seen how this was recorded. In order to deduce the correlation two fourfold tables were made. In the one the division was made between *Delicate* and *Normally Healthy*, in the other between *Normally Healthy* and *Strong*. Theoretically the fourfold divisions ought to be made everywhere where possible, and the weighted mean taken of the results to smooth out irregularities, but the labour is too great for practical purposes, and we must content ourselves with a few simple divisions.

(B) *Eye Colour.*—Our division was into light, medium, dark. The eyes corresponding to these classes are stated in the general instructions. See Appendix IA. For practical purposes the scale is one of the intensity of yellow pigmentation*. In this case, remembering that "medium" is rather a vague class, the fourfold division was taken at each of the four corners of the medium-medium category and the mean correlation of the four resulting tables taken to represent the actual correlation in eye colour.

(C) *Hair Colour.*—This is a character concerning which we sadly need a combined investigation on the part of a physiologist, a chemist, and an anthropologist. In saying this, I am not forgetting the pioneer work of Mr H. C. Sorby published in the *Journal* of this Institute†. I do not feel perfectly convinced that we have really got to the number of pigments involved. Even if we have, and there be just two, it by no means follows that our nomenclature enables us effectually to separate hair possessing these pigments in various degrees, still less to place in their right position in any scale the cases of blended pigments. Assume by way of illustration

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* Blue is to be considered as an absence of pigmentation.

† *Jour. Anthr. Inst.*, Vol. VIII. 1878, pp. 1—14.

only, that there existed two pigments, black and red. We might by placing red at one end of the scale and black at the other, obtain a single scale which would really be a double one, i.e., a scale of diminishing amounts of black pigment from one end, and of red from the other. In the one case the fairs are classed with red as marking an absence of black pigment and in the other case with the darks as marking an absence of red. Fourfold divisions of this table would then give the correlation between brethren either in the amount of red pigment or in the amount of black pigment. Unfortunately the observer comes across—besides a very deep red type of hair which seems to be pure red, and which shades, if enough individuals are taken, continuously away from "fair reds"—another red, a "dark red," which I found frequently described as "brown red" or "dark brown red," and which seems to be a blend of the red and dark pigments. The existence of these brown reds seems to me the difficulty of the single scale arrangement. It is on this account that some hair scale makers have placed the reds alongside the browns, but this appears to misplace the "fair reds" and "pure reds." I am at present working on the problem of a practical hair scale, and I am not at all certain that something corresponding to the artist's conception of "value" is not what we want, if we are to use hair colour as a character for investigations about inheritance. I merely refer to this method because I consider these hair colour results somewhat unsatisfactory and subject to revision and reclassification. There is another point also to which I must refer. I have found a distinct growth in children's hair colour with age. This, of course, has been recognized in a general way, but our data supply, as soon as we have settled our scale, the quantitative measure of it. Hence, exactly as in the case of head measurements, we ought really to allow for the growth change in hair before measuring the resemblance of brothers. Allowance for this growth, to judge from the effect of growth in other cases, might easily change the value of the correlation by 10 to 15 per cent. I hope to return to the problems of scale and growth in hair colour; meanwhile I would describe what I have done. The hair correlation tables have been worked out in four different ways, namely, by forming fourfold tables at each corner of the "brown-brown" category. By doing this I have endeavoured to allow for the position of the red-browns, which were classified under reds, i.e., whenever a division comes for the fourfold table between brown and dark, it is immaterial whether the reds are placed beyond the fairs, between fairs and browns, or between browns and darks. The results given for hair are the means of the four correlations found by working out the tables in four different ways. I believe on any system of "value*" my results will be approximately correct, but it would still need correction for growth, i.e., a sensible darkening in the fifteen years of life covered by our observations. On the whole, I publish the hair colour results with reservations†.

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* I hope shortly to be able to publish photographic measures of "value" in hair colour.

† I think since writing the above I have surmounted the difficulty of scale orders by applying the new method of contingency, which completely dispenses with any scale order: see *Drapers' Company Research Memoirs*, I. "On the Theory of Contingency and its Relation to Association and Normal Correlation." (Dulau and Co., Soho Sq., London.)

(D) *Curliness of Hair.*—Our three categories were smooth, wavy, curly. The results are the means of two computations, first with the division between smooth and wavy, and then with the division between wavy and curly.

(E) *Cephalic Index.*

(F) *Head Length.*

(G) *Head Breadth.*

(H) *Auricular Height.*

The method of investigating the degree of resemblance in these characters has been already referred to. We may note that, in all cases, the order of intensity in resemblance is head breadth, auricular height and head length. I confess to believing that some of this is due to greater difficulty in getting a true head length, than a true breadth or height, but I do not believe that this is the sole source of the divergence. I shall touch on this subject on another occasion when I come to deal with growth of head in children, meanwhile I would say that it appears to me that a pause arises in the growth of head length which is not perceptible, or at least not so perceptible, in the case of the growth of breadth or height. I should not be surprised to find that the on-coming of puberty affects the growth of head length differently from the growth of head breadth or height, and that a comparison for this character of brothers or sisters, one of whom has and the other of whom has not reached the age of puberty, may to some extent affect our results. This influence would not be fully allowed for by growth curves, as the age of puberty, especially in girls, seems to vary largely, even in members of the same family.

(I) *Athletic Power.*—While I have worked with only eight physical and eight mental characters, I have an additional character which it is needful to refer to here, and which it is difficult to class as purely physical. I mean athletic capacity. We may define the athletic individual as one who is not only keen on sports and games, but who is capable in them. This denotes a training and a *mental control* of hand and eye, and approaches psychical efficiency*. It might therefore be a problem to determine in which class of characters the athletic should be placed. The results, however, of dealing with athletics are from the standpoint of inheritance abnormally high. An examination of the schedules led me at once to the conclusion that much of this resemblance was wholly spurious. Certain schools, boys' public schools and the larger girls' schools, pride themselves on an athletic reputation; hence two brothers or two sisters at such schools are usually returned as an athletic pair. On the other hand, schools without an athletic reputation are too liable to return the two members of a pair as non-athletic, the teachers having little or no knowledge of the game capacity of their pupils. Hence arises the high value of resemblance in athletic power between the members of a pair of brothers or a pair of sisters. This resemblance is largely, perhaps 40 to 50 per cent., a result of a differentiation between the class of schools in which athleticism is a cult and the class in which it is not—the town or board school with little playground and no game training.

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* This is confirmed by the high correlations I have found to exist between athletic capacity and many psychical characters.

To complete the demonstration of this conclusion we need only turn to the mixed schools, whence our brother-sister pairs are drawn. These schools do not exhibit the athletic cult on the same scale, and we get quite a fair and reasonable value for the resemblance of brothers and sisters in athletic power. To obtain the correlation the fourfold division was taken between the athletic and non-athletic.

Psychical Characters.

(J) *Vivacity.*

(K) *Assertiveness.*

(L) *Introspection.*

(M) *Popularity.*

(N) *Conscientiousness.*

In all these five psychical characters, our schedule admitted of only three possibilities, i.e., the cross must be placed in the space allotted to either contrasted character, or on the dividing line between, marking a "betwixt and between" state of affairs. Our tables were prepared with a ninefold system of categories including a "betwixt" column and row. The "betwixts" were not, however, very numerous, and they were then halved or quartered as the case might be into the adjacent groups to save the great labour of working with four fourfold tables and averaging the four results.

(O) *Temper.*—Our categories were: *Quick-tempered*, *Good-natured*, and *Sullen*, with the usual system of "betwixts." In a very few instances sullen children were recorded who had occasional outbursts of quick temper. In this classification accordingly, some of the like difficulties arise that we have noted in the case of hair colour. To surmount these, first a division was made between quick temper and good temper, and the correlation found from the fourfold table thus reached. Secondly, the sullen were thrown in with the quick, and the whole classed as *Bad tempered* in contrast to *Good tempered*. In the first case we are measuring a certain phlegmatic character, in the second rather the extent of self-control. But the two divisions led to very sensibly the same results. Thus for girls we have the correlations:—

Division between Quick and Good temper: ·49.

Division into Good and Bad (Quick and Sullen) tempers: ·50.

The mean of the two results was then taken as a measure of correlation in the matter of temper.

(P) *Ability.*—We have already (p. 147) discussed this character at some length. All that seems necessary to add is that the division for the fourfold table was taken between *Intelligent* and *Slow Intelligent*.

(Q) *Handwriting.*—Some persons may be inclined to question whether this character is properly placed in the psychical class. Is it really a largely muscular characteristic? Personally I do not think it desirable to draw very rigid lines between the physical and psychical, and the present inquiry has much strengthened that opinion. But we have gone far further with handwriting than is obvious on the face of this paper, which is confined to inheritance; and, without anticipating results yet to be published, I would say that, quite contrary to my expectation, very sensible correlations exist between the psychical characters and the handwriting, which on the other hand has only very moderate or zero correlations with the physical characters. In school children at any rate, temper, probity and assertiveness are all correlated with the character of the handwriting, and I have little hesitation myself therefore in including it with the psychical rather than the physical group.

These remarks on the individual characters dealt with may enable the reader to understand something of the method adopted in analysing our material. They will at any rate suggest that many points have been considered and investigated which cannot be even touched upon here, but which have aided us in our classifications and general treatment*.

(iv) *Comparison of the Values found for the Inheritance of the Physical and Psychical Characters in Man.*

Thus far my whole object has been to describe the sources of my material, and to throw some light, perchance, on the new methods we have adopted in classification and computation. I have spent a considerable time over this latter topic, because to the anthropologist of the older school, the biometrician too often appears as a juggler in figures. It is impossible, perhaps, to help this at present, when the biometrician is introducing a new calculus, which cannot be learnt without hard work, and which cannot be handled without training. We are not endeavouring to discredit anthropology, but to furnish such branches of it as anthropometry and craniology with new tools—a little sharp-edged to the uninitiated who handle them incautiously—but which will raise anthropometry and craniology in the future into the category of the more exact sciences. Such must be my excuse for describing so fully, and yet, I fear, so ineffectually, the processes we have adopted. It is another point to ask you to admit that I came to this inquiry without prejudice. I expected *a priori* to find the home environment largely affecting the resemblance in moral qualities of brothers and sisters. I expected to find a spurious emphasis of the inheritance of the moral qualities owing to this environment. Putting any thought of prejudice on one side, accept for a moment the methods adopted, and listen—regardless of the drummers—to the broad results of the inquiry. You have in Table I. (see p. 140) the mean of the resemblance in physical characters of brothers and sisters from my records of family measurements. You have in Table III. the mean of the physical measurements of our school records—16 series in the first, 24 series in the latter. I venture to say that remembering the possible slips in measurement and in classification, there is not the slightest doubt that those two series absolutely confirm each other, and give a mean degree of resemblance of nearly ·5 between children of the same parents for physical characters. How much of that physical resemblance is due to home environment? You might at once assert that size of head and size of body are influenced by nurture, food, and exercise. It is quite true; even curliness may be subject to home influences. But what is the broad effect of such environment on our coefficients of heredity? Can any possible home influence be brought to bear on cephalic index, on hair colour, or eye colour? I fancy not, and yet these characters are within broad lines inherited exactly like the characters directly capable of being influenced by nurture and exercise. I am compelled to conclude that the environmental influence on physical characters, however great in some cases, is not to the first approximation a great disturbing factor when we consider

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* For example upwards of 120 correlations between physical characters, between psychical characters and between physical and psychical characters have been worked out, tending to throw light on the interrelationships of these supposed widely differentiated sides of the human character.

TABLE III.

Inheritance of the Physical Characters.

School Observations on Children.

Character.	Correlation.		
	Brothers.	Sisters.	Brother and Sister.
Health	·52	·51	·57
Eye Colour	·54	·52	·53
Hair „	·62	·57	·55
Hair Curliness	·50	·52	·52
Cephalic Index	·49	·54	·43
Head Length	·50	·43	·46
Head Breadth...	·59	·62	·54
Head Height	·55	·52	·49
Mean	·54	·53	·51
Athletic Power	·72	·75	·49

coefficients of fraternal resemblance in man. I do not believe it to be at all comparable with the irregularities that arise from random sampling and occasional carelessness in measurement or in appreciation of character.

Now turn to Table IV. giving the degree of resemblance in the mental and moral characters. What do we find in it? Perhaps slightly more irregularity in the values than in the case of the physical characters. The judgment required is much finer; and the classification is much rougher. Let me frankly admit the difficulties of the task, both for observers and computers. I will lay no weight whatever, if you like, on the second place of decimals. But what is the obvious conclusion? Why, that the values of the coefficient again cluster round ·5. If anything the average degree of resemblance for the psychical is rather less than for the physical, it certainly is not greater. Personally I would lay not a grain's weight on the difference.

TABLE IV.

Inheritance of the Mental Characteristics.

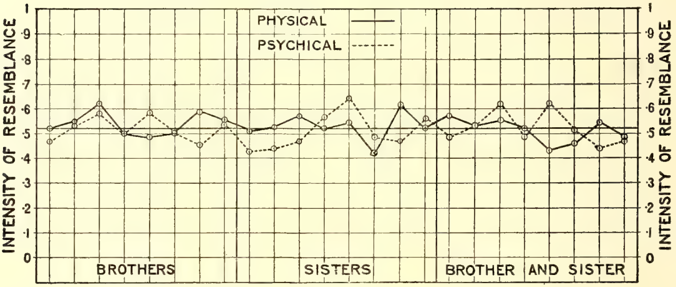
School Observations on Children.

Character.	Correlation.		
	Brothers.	Sisters.	Brother and Sister.
Vivacity	·47	·43	·49
Assertiveness	·53	·44	·52
Introspection	·59	·47	·63
Popularity	·50	·57	·49
Conscientiousness	·59	·64	·63
Temper	·51	·49	·51
Ability	·46	·47	·44
Handwriting	·53	·56	·48
Mean	·52	·51	·52

I have illustrated the whole result in Diagram XIII. The two lines representing physical and psychical qualities go bobbing up and down, and cutting and re-cutting one another. No wise man, however, would venture to assert that one or other is sensibly uppermost, or that any of those rises or falls have real significance. We are forced absolutely to the conclusion that the degree of resemblance of the physical and mental characters in children is one and the same.

It has been suggested that this resemblance in the psychical characters is compounded of two factors, inheritance on the one hand and training or environment on the other. If so, you must admit that inheritance and environment make up the resemblance in the physical characters. Now these two sorts of resemblance being of the same intensity, either the environmental influence is the same in both cases, or it is not. If it is the same, we are forced to the conclusion that it is insensible, for it cannot influence eye colour. If it is not the same, then it would be a most marvellous thing, that with varying degrees of inheritance, some mysterious force always modifies the extent of home influence, until the resemblance of brothers or sisters is brought sensibly up to the same intensity! Occam's razor will enable us at once to cut off such a theory. We are forced, I think literally forced, to the general conclusion that the physical and psychical characters in man are inherited within broad lines in the same manner, and with the same intensity. The average home environment, the average parental influence is in itself part of the heritage of the stock and not an extraneous and additional factor emphasising the resemblance between children from the same home.

Diagram XIII. *Comparison of Resemblance for Physical and Psychical Characters.*



But we are not yet at the end of our conclusions. By assuming our normal distribution for the psychical characters we have found, not only self-consistent results—linear regression, for example, as in the case of the inheritance of intelligence, but we have found the *same* degree of resemblance between physical and psychical characters. That *sameness* surely involves something additional. *It involves a like heritage from parents.* The degree of resemblance between children and parents for the physical characters in man may be applied to the degree of resemblance between children and parents for psychical characters. We inherit our parents' tempers, our parents' conscientiousness, shyness and ability, even as we inherit their stature, forearm and span.

At what rate is that? I show you a table (*see* Table V.), which represents our present knowledge of parental inheritance in man*, and in other species. I venture to say that—within broad lines—the physical characters are inherited at the same rate in man and in the lower forms of life. The resemblance of parent and offspring is again roughly ·5.

TABLE V.

Parental Inheritance in Different Species.

Species	Character	Mean value	No. of pairs used	Source	Remarks
Man	Stature	·506	4886	*Biometrika*, Vol. II. p. 358	—
"	Span	·459	4873	ditto	—
"	Forearm	·418	4866	ditto	—
"	Eye colour	·495	4000	*Phil. Trans.*, Vol. 195, p. 106	—
Horse	Coat colour	·522	4350	*Phil. Trans.*, Vol. 195, p. 93	—
Basset Hound ...	Coat colour	·524	823	*R. S. Proc.*, Vol. 66, p. 154	Dams only used
Greyhound ...	Coat colour	·507	9279	Unpublished data for two characters	Dams and sires both used
Aphis (*Hyalopterus Trirhodus*) ...	$\frac{\text{Right antenna}}{\text{Frontal breadth}}$	·439	368	*Biometrika*, Vol. I. p. 139	Ratios only taken to free from growth factor
Daphnia *Magna* ...	$\frac{\text{Protopodite}}{\text{Body length}}$	·466	96	*R. S. Proc.*, Vol. 65, 1899	

What conclusion flows upon us irresistibly from the inspection of such a table? Why, that the psychical characters are not features which differentiate man from the lower types of life. If they are inherited like man's physical characters, if they are inherited even as the protopodite of the water flea, what reason is there for demanding a special evolution for man's mental and moral side? We look upon the universe and wonder. The man of science probes a little deeper into nature than the ordinary mortal, but the deeper he probes, the greater his wonder, for the more complex and mysterious the universe appears. Do you wish to draw the line of mystery at living forms? Look at the sky on a clear night, and realise that while astronomers have *described* the motions of a tiny corner of the universe, they have not the least explanation of how and why those motions are taking place.

Nay, take the least, apparently most inert particle of metal, and remember that if modern physical views are correct, millions, probably billions of small corpuscles are in relative motion within it, with a complexity and yet probably with an underlying order as great as in the starry universe, even if they be on a totally different scale. Remember that we have scarcely touched the fringe of a description of those motions, and that their *why* is as inexplicable to us as the motions of the celestial bodies themselves. Note all this, and ask yourselves if there be less mystery in the motions of non-living than of living things. You may call a man who would link up the motion of living to non-living things a materialist. But the materialist in no way lessens the endless mystery of the universe. He knows not what matter is, why it moves, or how he comes to be conscious of its motion. He is but fulfilling the task of science, the linking of mystery to mystery, by bringing them under one common wider conception of the ultimately inexplicable. So it is when we pass from the lower living forms to man. If we see that his physical development is closely allied to brute development, we link mystery to mystery in a common description—a law if you like—but it removes no grain of the ultimate mystery of why life is there, and why it develops. Lastly, turning to the psychical character of man, to some the greatest of all mysteries, we link it up to the physical. We see the man, not only physically, but morally and mentally, the product of a long line of ancestry. We realise that evolution and selection play no greater, and play no less a part in the production of the psychical character than in the production of the physique of man. Once fully realise that the psychic is inherited in the same way as the physical, and there is no room left to differentiate one from the other in the evolution of man. Realise all this, and two mysteries have been linked into one mystery, but the total mystery is no less in magnitude, and no more explicable than it was before. We know not why living forms vary, nor why either physical or psychical characters are inherited, nor wherefore the existence at all of living forms, and their subjection to the great principle of selective evolution. We have learnt only a law common to the physical and the psychical; we have not raised the one or debased the other, because in a world where the ultimate source of change is utterly inexplicable, whether you strive to perceive it through matter like a physicist, through the lower living forms like the biologist, or through man like the anthropologist, all terminology like higher and lower is futile. Where the mystery is absolute in all cases, there can be no question of grade.

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* Taken from a memoir: "On the Laws of Inheritance in Man. I. Inheritance of the Physical Characters." *Biometrika*, Vol. II. p. 379.

But I would not leave you with a mere general declaration that all is mystery, that scientific ignorance of the ultimate is profound. Rather I would emphasise what I have endeavoured to show you to-night, that the mission of science is not to explain but to bring all things, as far as we are able, under a common law. Science gives no real explanation, but provides comprehensive description. In the narrower field it has to study how its general conceptions bear on the comfort and happiness of man. Herein, I think, lies especially the coming function of anthropology. Anthropology has in the first place to study man, to discover the sequence of his evolution from his present comparative stages and from his past history. But it cannot halt here; it must suggest how those laws can be applied to render our own human society both more stable and more efficient. In this function it becomes at least the handmaiden of statecraft, if indeed it were not truer to call it the preceptor of statesmen.

If the conclusion we have reached to-night be substantially a true one, and for my part I cannot for a moment doubt that it is so, then what is its lesson for us as a community? Why simply that geniality and probity and ability may be fostered indeed by home environment and by provision of good schools and well equipped institutions for research, but that their origin, like health and muscle, is deeper down than these things. They are bred and not created. That good stock breeds good stock is a commonplace of every farmer; that the strong man and woman have healthy children is widely recognized too. But we have left the moral and mental faculties as qualities for which we can provide amply by home environment and sound education.

It is the stock itself which makes its home environment, the education is of small service, unless it be applied to an intelligent race of men.

Our traders declare that we are no match for Germans and Americans. Our men of science run about two continents and proclaim the glory of foreign universities and the crying need for technical instruction. Our politicians catch the general apprehension and rush to heroic remedies. Looking round impassionately from the calm atmosphere of anthropology, I fear there really does exist a lack of leaders of the highest intelligence, in science, in the arts, in trade, even in politics. I do seem to see a want of intelligence in the British merchant, in the British professional man and in the British workman. But I do not think the remedy lies solely in adopting foreign methods of instruction or in the spread of technical education. I believe we have a paucity, just now, of the better intelligences to guide us, and of the moderate intelligences to be successfully guided. The only account we can give of this on the basis of the results we have reached to-night is that we are ceasing as a nation to breed intelligence as we did fifty to a hundred years ago. The mentally better stock in the nation is not reproducing itself at the same rate as it did of old; the less able, and the less energetic, are more fertile than the better stocks. No scheme of wider or more thorough education will bring up in the scale of intelligence hereditary weakness to the level of hereditary strength. The only remedy, if one be possible at all, is to alter the relative fertility of the good and the bad stocks in the community. Let us have a census of the effective size of families among the intellectual classes now and a comparison with the effective size of families in the like classes in the first half of last century. You will, I feel certain, find, as in the case of recent like censuses in America, that the intellectual classes are now scarcely reproducing their own numbers, and are very far from keeping pace with the total growth of the nation. Compare in another such census the fertility of the more intelligent working man with that of the uneducated hand labourer. You will, I again feel certain, find that grave changes have taken place in relative fertility during the last forty years. We stand, I venture to think, at the commencement of an epoch, which will be marked by a great dearth of ability. If the views I have put before you to-night be even approximately correct, the remedy lies beyond the reach of revised educational systems; we have failed to realise that the psychical characters, which are, in the modern struggle of nations, the backbone of a state, are not manufactured by home and school and college; they are bred in the bone;

and for the last forty years the intellectual classes of the nation, enervated by wealth or by love of pleasure, or following an erroneous standard of life, have ceased to give us in due proportion the men we want to carry on the ever-growing work of our empire, to battle in the fore-rank of the ever intensified struggle of nations.

Do not let me close with too gloomy a note. I do not merely state our lack. I have striven by a study of the inheritance of the mental and moral characters in man to see how it arises, and to know the real source of an evil is half-way to finding a remedy. That remedy lies first in getting the intellectual section of our nation to realise that intelligence can be aided and be trained, but no training or education can *create* it. You must breed it, that is the broad result for statecraft which flows from the equality in inheritance of the psychical and the physical characters in man.

Addendum, April, 1904.

I hardly know whether it is needful to refer here to a recent article by Mr C. Spearman in *The American Journal of Psychology* (Vol. xv. pp. 72—101), criticising my results for the similarity of inheritance in the physical and psychical characters. Without waiting to read my paper in full he seems to think that I must have disregarded "home influences" and the personal equation of the school teacher. He proceeded to 'correct' my results for the error of what he calls dilation on the double basis (i) of a formula invented by himself, but given without proof, and (ii) of his own experience that two observers' observations or measurements of the same series of two characters were such that the correlation between their determinations was ·58 in one case and ·22 in the other. The formula invented by Mr Spearman for his so-called 'dilation' is clearly wrong, for applied to perfectly definite cases, it gives values greater than unity for the correlation coefficient. As to his second basis, all I can say is that if the correlation between two observers of the same thing in Mr Spearman's case can be as low as ·22, he must have employed most incompetent observers, or given them most imperfect instructions, or chosen a character suitable for random guessing rather than observation in the scientific sense. Mr Spearman says that "it is difficult to avoid the conclusion that the remarkable coincidence announced between physical and mental heredity can be more than mere accidental coincidence" (p. 98). I think I may safely leave him to calculate the odds for or against this most remarkable "mere accidental coincidence." I may take occasion later to return to Mr Spearman's paper, but at present it may suffice to say that not only are his formulae, especially for probable errors, erroneous, but he quite misunderstands and misuses partial correlation coefficients (p. 95). Further his statements as to the number of cases desirable for an experiment would be extremely dangerous, if they were in the least likely to be generally regarded. In particular one can only pillory such an assertion as that "It was shown in the same part that the size of the probable error also varies according to the method of calculation—and to such an extent that twenty cases treated in one of the ways described [Mr Spearman's own new method] furnish as much certitude as 180 in another more usual way" (p. 100). Perhaps the best thing at present would be for Mr Spearman to write a paper giving algebraical proofs of all the formulae he has used, and if he did not discover their erroneous character in the process, he would at least provide tangible material for definite criticism, which it is difficult to apply to mere unproven assertions.

APPENDIX IA.

[*Any Teacher willing to give assistance in these observations—an assistance which will be duly acknowledged in the final publication of results—is requested to communicate with* Professor KARL PEARSON, F.R.S., *University College, London.*]

GENERAL DIRECTIONS FOR FILLING UP DATA PAPERS OF COLLATERAL HEREDITY*.

1. The object of this investigation is two-fold :

   (i) To ascertain the degree of resemblance, mental and physical, between children of the same parents.

   (ii) To discover, if possible, whether there is any relationship between the external shape of the head and a teacher's estimate of the general grade of ability of the pupil.

Co-operators are warned *ab initio* that no inferences whatever can be drawn from individual instances or from a small series of measurements. The numerical quantities to be determined are small, and it is only when large masses of observations have been collected from many quarters and have been reduced that reliable inferences can be drawn.

2. The measurements and estimates are to be made on :

   (i) Pairs of brothers (white data paper).

   (ii) Pairs of sisters (pink data paper).

   (iii) Pairs of brothers and sisters (blue data paper).

Care must be taken that the right coloured data paper is selected.

The names of the measured are only required in case there should be need for the verification of any entry, and they will be treated as strictly confidential. Initials, in fact, may be used where it seems desirable, if the observer keeps a key to them for the purpose of reference should reference be required.

The observer should have known *well* both members of the pair measured for at least six months, and, if possible, for a much longer period. The classification is purposely made rather wide and indefinite in order that there may be less hesitation in classifying. What is needed is the general impression of a teacher who has carefully observed his or her pupils.

For both physique and ability it is very desirable that the observer should consult, where it is possible, one or more colleagues before filling up the data paper.

To give some confidence in the scales adopted, I may remark that in response to my appeal in the *Journal of Education*, I received details of some 150 boys and girls tested for ability by three observers independently (language, science, and mathematical teachers) and belonging to half-a-dozen different schools. The agreement in classification was complete in more than 80 per cent. of cases, and only differed by as much as two classes in about 5 per cent. of cases†. This degree of accordance is sufficient for the present statistical purposes.

3. I. *Physique*. In making the record, attention should be paid not only to appearance, energy, and athletic qualities, but to irregularity of attendances owing to ill-health, frequency of visits to school-infirmary, etc.

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* The quantitative laws of heredity, such as we have reached at present, do not apply to individual cases, but only to the averages of large numbers. It is important to insist on this, because more than one of my helpers on hearing the results of a particular research has seemed disappointed, remarking that the law does not hold for the family X or the brothers Y.

† Even this amount of divergence would probably have disappeared after a consultation with regard to the individuals classified.

II. *Ability.* (*a*) Some account of this scale will be found in the *Journal of Education* for September, 1898, which it might be well for the observer to examine. The following may help to show the significance of the terms :

Very Dull. Capable of holding in their minds only the simplest facts, and incapable of perceiving or reasoning about the relationship between facts.

Slow Dull. Capable of perceiving relationship between facts in some few fields with long and continuous effort; but not generally, or without much external assistance.

Slow. Very slow progress generally, but with time and continual care progress will be made.

Slow Intelligent. Slow generally, although possibly more rapid in certain fields. Quite sure of knowledge when once acquired.

Intelligent. Ready to grasp and capable of perceiving facts in most fields; capable of good progress without much effort.

Quick Intelligent. Very bright and quick both in perception and in acquirement, and this not only of customary, but of novel, facts. Ready to reason rightly about things on purely self-initiative.

Inaccurate-Erratic. Capable of perceiving facts, but quick to form erroneous conclusions about them, illogical and erratic in reasoning.

(*b*) *Handwriting.* If possible, in addition to this classification, get the pair under investigation to write the last lines of Lord Macaulay's *Lay of Horatius*, with their own signatures on the back of the data paper.

(*c*) *Work.* If the individual be good at several subjects, put a cross against all these in the first row; as well as the strongest subject in the next row; if the individual be good at none, make no entry in the first row, but only in the second row, where *best at* must be interpreted in this case as *least bad at.* The individual should be asked his favourite subject and favourite game. Mathematics covers Arithmetic and Geometry: Descriptive Science includes Botany, Experimental Physics, Physiography, etc.

III. *Head Measurements.* These are to be made with the head-spanner, full directions for the use of which are given in its case.

IV. *Hair.* Comment seems unnecessary.

V. *Eyes.* Light covers blue of all shades, light grey, very light green; medium covers dark grey, green, light chestnut, orange and grey combined ; dark covers dark chestnut, light and dark brown, black.

VI. *Relative Characters.* This entry is needful for the numerical reduction of the statistics in those cases in which both brothers have been given the *same* class, otherwise no use should be made of it.

If the characteristic be equally strong in both, write equal, instead of putting a cross.

VII. If the alternative characteristics are neither possessed in a marked degree, place the cross on the dividing line.

VIII. *General Remarks.* Under this heading it may be useful *occasionally* to note any marked physical or mental characteristic of the pair. Care should, however, be taken not to lay greater stress on points of resemblance than on points of diversity.

4. It is most desirable that the head-spanners should not be kept longer than four to six weeks, in order that they may be sent on as rapidly as possible to other schools. They should be returned with the stamped and addressed labels. Any school anthropometrical laboratory desiring to procure a head-spanner of the present pattern, can do so at a cost of 19*s.* 6*d.*, from the Cambridge Scientific Instrument Company, Carlyle Road, Cambridge.

The spanners need to be carefully handled. Should any part be broken or lost the box with the spanner should be returned at once, in order that it may be repaired without delay and again sent out for use.

Any special inquiries should be addressed to me, at University College, London.

KARL PEARSON.

Appendix Ib.

Data Paper for Collateral Heredity Investigations.

B. SISTER-SISTER SERIES.
(Whole, not half sisters.)

No. in whole series.
(Not to be filled in.)

Please return this Paper to Professor KARL PEARSON, F.R.S., University College, London.

School :

Observer :

No. in School Series

Date :

Place a cross against the class of each sister under as many headings as possible, except under III and VIII. Please read first the General Directions.

	Elder Sister.	Younger Sister.
Name		
Age		
District of Home		

I. Physique :

	Very Strong.	Strong.	Normally Healthy.	Rather Delicate.	Very Delicate.	Athletic.	Non-Athletic.
Elder Sister ...							
Younger Sister ..							

II. Ability : (*a*) *General Scale.*

	Quick Intelligent.	Intelligent.	Slow Intelligent.	Slow.	Slow Dull.	Very Dull.	Inaccurate-Erratic.
Elder Sister ...							
Younger Sister ...							

(*b*) Handwriting :
(*See Back.*)

	Very Good.	Good.	Moderate.	Poor.	Bad.	Very Bad.
Elder Sister ...						
Younger Sister ...						

(*c*) Work :

		Classics.	Modern Languages.	History.	Mathematics.	Descriptive Science.	Drawing.	Singing, Music.
Elder Sister ...	Good at ...							
	Best at ...							
	Likes best							
Younger Sister	Good at ...							
	Best at ...							
	Likes best							

(*d*) Games or Pastimes :

	Elder Sister.	Younger Sister.
Likes ...		
Good at ...		

III. Head Measurements :

	Length.	Breadth.	Height.	*a*.	*b*.	*c*.
Elder Sister ...						
Younger Sister ...						

(*a*), (*b*), (*c*), Indices (not to be filled in).

IV. Hair :

	Red.	Fair.	Brown.	Dark.	Jet Black.	Smooth.	Wavy.	Curly.
Elder Sister ...								
Younger Sister ...								

V. Eyes :

	Light.	Medium.	Dark.
Elder Sister ...			
Younger Sister ...			

VI. Relative Capabilities :

This is *only* to be filled in in those cases wherein the two sisters fall into the *same* class.

	Physique, stronger in	More Athletic.	Ability, greater in	Handwriting, better in	Hair, darker in	Eyes, darker in
Elder Sister ...						
Younger Sister ...						

VII. Character, etc. :

	Noisy.	Quiet.	Self-conscious.	Unself-conscious.	Self-assertive.	Shy.	Conscientiousness.		Popular.	Unpopular.	Temper.		
							Keen.	Dull.			Quick.	Good-natured.	Sullen.
Elder Sister ...													
Younger Sister ...													

VIII. General Remarks. Add here any striking features of resemblance or dissimilarity in the sisters.

Elder Sister ...

Younger Sister ...

[On the back of the Schedule spaces were arranged for samples of the handwriting.]

APPENDIX II.

Observers and Schools contributing to the Data upon which this Memoir is based.

Aberdeen, A. N. Meldrum; Ferry Hill Public School, J. D. Anderson. *Aberuthven* School, J. M. S. Math. *Acocks Green*, Wellesbourne House School, O. Sunderland. *Aldenham* School, F. B. Stead. *Alresford*, Swanaton School, W. L. W. Eyre. *Barnard Castle*, County School, F. Hodson. *Bakewell*, Lady Manners' School, H. Martin. *Berwick*, Berwickshire High School, H. S. Mabbatt. *Birmingham*, King Edward's School, F. M. McCarthy; King Edward's School, C. J. Wood; King Edward's School for Girls, M. J. Nimmo and A. L. Parmenter. *Bradford-on-Avon*, Winsley and Turley National School, Alice E. Griffiths. *Bridgend*, County School, W. A. Whittan. *Bridgewater*, St John's School, E. M. Lucas. *Brighton*, Brighton and Hove High School for Girls, R. Mayhew. *Bristol*, Two-Mile Hill Board School, A. F. Bateman. *Buckhurst Hill*, Oakfield School, E. Linder. *Burghead* Public School, M. Brenner. *Burnley*, Higher Grade and Science School, F. H. Hibber. *Cardenden*, Craigderran School, David Rorie. *Cardiff*, Eleanor Street Boys' School, A. C. Badcoe; Intermediate School for Boys, A. Abbatt. *Carlisle*, High School for Girls, A. Beavor and G. Whiting. *Caterham*, Congregational School, F. W. G. Foat. *Cheltenham*, Ladies' College, Catherine E. Berridge. *Chesterfield*, Hipper Street School, S. Steel. *Clacton-on-Sea*, Clacton College, H. Picton. *Clapham*, High School for Girls, M. Cave and Mrs Woodhouse. *Congleton*, St James' School, W. F. Warburton. *Cork*, High School for Girls, H. A. Martin. *Darlington*, Bowes School, D. L. Smith. *Dereham*, Swanton Morley National School, J. Lewton Brain. *Dewsbury* Grammar School, G. Rowland. *Dulwich*, Alleyn's School, J. V. H. Coates; Dulwich College, H. Brereton Baker; Dulwich Village Evening Continuation School, C. T. Hunt. *Dollar* Public School, J. Begg. *Dundee*, Monikie School, P. Grant. *Durham* School, J. T. Johnson. *Duffus* Public School, J. W. Garrigall. *Epsom*, The College, S. R. Browne. *Ferry Hill*, Bishopton School, T. G. Frankton. *Edinburgh*, Fettes College, C. J. N. Fleming and W. I. Sargent. *Fochaber*, Speymouth Public School, A. Geddie. *Folkestone*, Sidney Street Board School, J. A. Hugill. *Glossop*, Arundel School, R. H. Dickinson. *Grangemouth*, Grange Higher Grade Science School, F. W. Maryon. *Grantham*, North Raunceby Church School, A. W. M. Drew and W. H. Baily. *Great Ayton*, Friends' School, F. R. Arundel. *Guernsey*, Island of (numerous schools), E. W. Adair and S. Butler. *Halifax* Higher Board School, W. Dycke. *Harrogate*, Western Board School, J. W. Hammond. *Haslemere*, Fernhurst Board School, H. Watts. *Hassocks*, Clayton School, L. H. Beecher-Shand. *Handsworth*, Grammar School, S. R. Hart. *Haywards Heath*, National Schools, A. J. Mouncher. *Hinckley*, Elementary School, O. C. Hirst. *Hornsey*, Board School, J. C. Hudson. *Huntley*, Corse Public School, A. C. Rathway. *Ilkeley*, Grammar School, F. T. Cramphorn. *Isle of Wight*, Chorley School, G. E. Jeans. *Keighley*, Kiedwich School, T. Appleby. *Keswick*, Keswick School, S. Horton Barnard. *Landewednack*, Board School, J. Carwardine. *Leek*, High School, T. L. Warrington. *Leighton Buzzard*, Linslade School, G. F. Andrill. *Lerwick*, Widows' Asylum, J. Allen. *Leyton*, Elementary School, F. J. Chittenden; Technical Institute, H. Hills. *Lisburn*, Ulster Provincial School, W. D. Braithwaite. *Llandebie* School, T. Mathews. *Liverpool*, High School for Girls, E. Canning; Liverpool Institute, W. S. Saul. *Londonderry*, Fahan School, W. A. Dickson. *Lyme Regis*, National School, J. Radford. *London*, University College School, J. L. Paton and Staff; Whitechapel Road Foundation School, F. Dixon; Priory Grove Board School, W. R. Suddeley; Fernhead Road School, J. C. Bedwell; Goswell Road, St Thomas', Charterhouse, W. W. Woodward; New Southgate, High School, J. Fairquire; Chelsea, Cook's Ground Board School, D. H. Hodge; Walworth, Michael Faraday School, T. M. Upfield; Titchborne Street, St John's

Girls' School, A. McGillvray; Radnor Street Wesleyan School, J. W. Parkinson; Fernham Street Girls' Board School, S. Carter; Dulwich, High School for Girls, M. Barwell; Highbury, High School for Girls, M. Minasi; Notting Hill, High School for Girls, T. F. Grünbaum; Camden Town, North London Collegiate School for Girls, S. Bryant; Limehouse, St Anne's Schools, C. J. Carter; Hampstead, Soldiers' Daughters' Home, C. D. Fawcett; Morley College, J. Denton; Notting Hill School, M. M. Adamson; Limehouse, Higher Grade Board Schools, Thomas Street, J. Crabtree; Old Charton Girls' School, A. Baker; Hampstead, King Alfred's School, J. Russell; Christ's Hospital, C. E. Browne. *Manchester*, Hulme Grammar School, C. H. Crombie; High School for Girls, C. Coignou; Withington, Lady Barn House School, C. Herford. *Mansfield*, Brunt's Technical School, C. E. Stacey. *Margate*, New Cross Street Board School, E. Parker. *Markinch*, Star Public School, Wm. McLachlan. *Marston Green*, Cottage Homes, W. J. Rees. *Merthyr Tydfil* School, M. J. Swift. *Milford Haven* County School, L. Jones. *Morpeth*, Netherwitton Board School, J. Anderson. *Newark*, Beacon Hill School, W. A. Greames. *Newbury* School, C. Cecil Fry; Donnington School, Mrs Bell. *Newcastle-on-Tyne*, Central High School for Girls and other schools, E. W. N. Williams. *Newton Stewart*, Ewart High School, C. S. Dougall. *Norwich*, Angel Road Board School, B. H. Barber. *Nottingham*, Berridge Road Girls' Board School, A. N. Stone; Morley House, B. Smith; Waverley School, H. T. Facon. *Oxford*, High School for Girls, E. Macdonald; Abbey Road School, Miss Sheppard. *Pembroke Dock*, County School, G. W. West. *Pemberton*, St John's Schools, J. T. Milward. *Peterborough*, Fitzwilliam School, G. E. Holmes. *Peterhead* Academy, J. Don. *Petersfield*, Bedales School, T. J. Garstang. *Pinner*, Woodridings School, Z. Haes. *Polperro* School, F. H. Perry-Coste. *Pontefract*, Ackworth School, G. E. Bell. *Pontypridd*, Wesleyan School, W. H. Rees. Mill Street Higher School, J. Farr. *Portsmouth*, High School for Girls, M. M. Adamson. *Pwlheli*, County School, J. W. Evans. *Reigate*, Church High School, E. E. Ardington. *Richmond* (Surrey), County School, A. E. Buckhurst; Richmond Hill School, H. D. Greig. *Royston*, Littlington School, W. C. Whitehead. *Saffron Walden*, Friends' School, E. W. Sawdon. *St Leonards-on-Sea*, Silverhill Girls' School, E. H. Woodd. *Sheffield*, Westbourne School, Miss Sims. *Shrewsbury*, Criggian School, R. Brack; Murivane High School for Girls, G. M. Wise. *South Shields* School, R. Sanderson. *Southwold*, St Felix School, C. M. Sant. *Spennymore* School, H. Askew. *Spilsby*, Spendleby School, A. Teare. *Stranraer*, Ardwell School, D. Thomson. *Swansea* Grammar School, E. H. Tripp. *Sydenham* School, R. Lulham. *Taunton*, King's College, E. B. Vincent. *Tavistock*, Kelly College, P. L. Andrews. *Tottenham* High School, L. F. Ushendoor. *Upholland* Grammar School, D. L. Rennard. *Warrington*, Penketh School, W. E. Brown. *Wellington* College, G. E. Blundell and H. P. Fitzgerald. *West Ham*, Castor House Board School, R. Symes. *Whitehaven*, Girls' School, W. Blackmore. *Winchester* College, W. B. Croft. *Wimbledon*, High School for Girls, Miss Knight. *Windlesham* Board School, J. Simms. *Winscombe*, Sicot School, B. Lean. *Woodford*, Wanstead College, J. B. Martin. *Wragby* School, T. Dixon-Spain. *York*, High School for Girls, M. Leader. *Yeovil*, Kington School, E. H. Davison. *Yiewsley*, St Matthew's Schools, J. J. Wade. *Ystalyfera*, County School, A. B. Gully; and other schools.

APPENDIX III.—DETAILED TABLES.

I. PHYSICAL CHARACTERS.

HEALTH.

A (i).

Brother-Brother.

First Brother.

		Very strong.	Strong.	Normally healthy.	Rather delicate.	Very delicate.	Totals.
Second Brother.	Very strong	24	31	11·5	4	—	70·5
	Strong	31	342	163·75	65·75	3	605·5
	Normally healthy	11·5	163·75	588·5	137·25	6	907
	Rather delicate	4	65·75	137·25	95	11	313
	Very delicate	—	3	6	11	2	22
	Totals	70·5	605·5	907	313	22	1918

A (ii).

Sister-Sister.

First Sister.

		Very strong.	Strong.	Normally healthy.	Rather delicate.	Very delicate.	Totals.
Second Sister	Very strong....	44·5	38·5	17·5	8·5	—	109
	Strong	38·5	306·5	154·5	74	5	578·5
	Normally healthy	17·5	154·5	411	201·5	19	803·5
	Rather delicate	8·5	74	201·5	166	28·5	478·5
	Very delicate	—	5	19	28·5	15	67·5
	Totals	109	578·5	803·5	478·5	67·5	2037

A (iii).

Brother-Sister.

Brother.

		Very strong.	Strong.	Normally healthy.	Rather delicate.	Very delicate.	Totals.
Sister.	Very strong	46	15	7	4	—	72
	Strong	35	174·5	64	22·5	1	297
	Normally healthy	17	85·25	191·75	50·5	3	347·5
	Rather delicate	9	34·25	69·75	48	3	164
	Very delicate	1	2	1	2·5	6	12·5
	Totals	108	311	333·5	127·5	13	893

EYE COLOUR.

B (i). *Brother-Brother.*

First Brother.

		Light.	Medium.	Dark.	Totals.
Second Brother.	Light	558	190	81·5	829·5
	Medium	190	426·5	122	738·5
	Dark	81·5	122	228·5	432
	Totals....	829·5	738·5	432	2000

B (ii). *Sister-Sister.*

First Sister.

		Light.	Medium.	Dark.	Totals.
Second Sister.	Light	438·5	196·5	71·5	706·5
	Medium	196·5	598	136	930·5
	Dark	71·5	136	257·5	465
	Totals....	706·5	930·5	465	2102

B (iii.) *Brother-Sister.*

Brother.

		Light.	Medium.	Dark.	Totals.
Sister.	Light	206·5	66·5	33	306
	Medium	86	208·25	46·25	340·5
	Dark	28	53·25	104·25	185·5
	Totals....	320·5	328	183·5	832

HAIR COLOUR.

C (i).

Brother-Brother.

First Brother.

		Red.	Fair.	Brown.	Dark.	Jet black.	Totals.
Second Brother.	Red	30·5	23	16	12	—	81·5
	Fair	23	416	158	67·75	·25	665
	Brown	16	158	394	98·25	8·25	674·5
	Dark....	12	67·75	98·25	328·5	19	525·5
	Jet black	—	·25	8·25	19	10	37·5
	Totals	81·5	665	674·5	525·5	37·5	1984

C (ii).

Sister-Sister.

First Sister.

		Red.	Fair.	Brown.	Dark.	Jet black.	Totals.
Second Sister.	Red	31	22	19	14	1	87
	Fair	22	474	195·5	47·5	—	739
	Brown	19	195·5	474	162·5	4·5	855·5
	Dark....	14	47·5	162·5	206	6·5	436·5
	Jet black	1	—	4·5	6·5	4	16
	Totals	87	739	855·5	436·5	16	2134

C (iii).

Brother-Sister.

Brother.

		Red.	Fair.	Brown.	Dark.	Jet black.	Totals.
Sister.	Red	12	9·5	12·5	5	—	39
	Fair	10·5	198·5	73	29·5	—	311·5
	Brown	4	72	138·5	57	3	274·5
	Dark....	5	32·5	52·5	91	10	191
	Jet black	—	1	3	4	5	13
	Totals	31·5	313·5	279·5	186·5	18	829

CURLINESS OF HAIR.

D (i). *Brother-Brother.*

First Brother.

		Smooth.	Wavy.	Curly.	Totals.
Second Brother.	Smooth	1556·5	111·5	34·5	1702·5
	Wavy	111·5	134·5	20	266
	Curly	34·5	20	11	65·5
	Totals....	1702·5	266	65·5	2034

D (ii). *Sister-Sister.*

First Sister.

		Smooth.	Wavy.	Curly.	Totals.
Second Sister.	Smooth	937·5	190·5	98	1226
	Wavy	190·5	213·5	52	456
	Curly	98	52	76	226
	Totals....	1,226	456	226	1908

D (iii). *Brother-Sister.*

Brother.

		Smooth.	Wavy.	Curly.	Totals.
Sister.	Smooth	395·5	24	12	431·5
	Wavy	106·5	33	11	150·5
	Curly	49	11	17	77
	Totals....	551	68	40	659

E (i).

Cephalic Index. Brother-Brother.

First Brother.

Second Brother.

	67—68	68—69	69—70	70—71	71—72	72—73	73—74	74—75	75—76	76—77	77—78	78—79	79—80	80—81	81—82	82—83	83—84	84—85	85—86	86—87	87—88	88—89	89—90	90—91	91—92	Totals.
67—68	—	1	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
68—69	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
69—70	—	—	2	—	1	—	—	1	2	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	8
70—71	1	1	—	—	2	2	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8
71—72	—	—	1	2	—	2	2	2	5	2	4	2	—	1	1	—	1	—	1	—	—	—	—	—	—	26
72—73	1	—	—	2	2	2	3	1	3	2	2	1	3	1	—	—	—	—	—	—	—	—	—	—	—	23
73—74	—	—	—	1	2	3	6	5	7	10	7	3	2	1	1	1	—	—	—	—	—	—	—	—	—	49
74—75	—	—	1	—	2	1	5	6	11	8	11	13	7	6	1	3	1	1	—	—	—	—	1	—	—	78
75—76	—	—	2	1	5	3	7	11	16	18	24·5	34	15	5	4	8	2	1	—	—	—	—	—	—	—	156·5
76—77	—	—	—	—	2	2	10	8	18	20	24	40·5	23	17	6	6	1	2	—	2	—	—	—	—	—	181·5
77—78	—	—	—	—	4	2	7	11	24·5	24	38	39	27·5	19·5	13	10	10	3	3	—	1	—	—	—	—	236·5
78—79	—	—	—	—	2	1	3	13	34	40·5	39	50	36·5	25·5	20	12	6	6	2	2	1	—	—	—	—	293·5
79—80	—	—	—	—	—	3	2	7	15	23	27·5	36·5	34	23	21	14·5	12	1	3	3	—	1	1	—	—	227·5
80—81	—	—	—	—	1	1	1	6	5	17	19·5	25·5	23	26	24	8·5	15	4	4	1	—	—	—	—	—	181·5
81—82	—	—	1	—	1	—	1	1	4	6	13	20	21	24	26	17	8	9	2	—	—	1	1	—	—	156
82—83	—	—	1	—	—	—	1	3	8	6	10	12	14·5	8·5	17	10	15	15	5	2	1	—	—	1	—	130
83—84	—	—	—	—	1	—	—	1	2	1	10	6	12	15	8	15	8·5	6·5	3	4	—	—	—	—	—	93
84—85	—	—	—	—	—	—	—	1	1	2	3	6	1	4	9	15	6·5	4·5	3	1	—	1	—	—	—	58
85—86	—	—	—	—	1	—	—	—	—	—	3	2	3	4	2	5	3	3	2	1	1	1	—	—	—	31
86—87	—	—	—	—	—	—	—	—	—	2	—	2	3	1	—	2	4	1	1	4	3	—	—	—	—	23
87—88	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	1	—	—	1	3	—	—	—	—	—	7
88—89	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	1	1	—	—	—	—	—	—	4
89—90	—	—	—	—	—	—	—	1	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	1	4
90—91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
91—92	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1
Totals	3	2	8	8	26	23	49	78	156·5	181·5	236·5	293·5	227·5	181·5	156	130	93	58	31	23	7	4	4	1	1	1982

E (ii).

Cephalic Index. Sister-Sister.

First Sister.

Second Sister.

	62·5—63·5	63·5—64·5	64·5—65·5	65·5—66·5	66·5—67·5	67·5—68·5	68·5—69·5	69·5—70·5	70·5—71·5	71·5—72·5	72·5—73·5	73·5—74·5	74·5—75·5	75·5—76·5	76·5—77·5	77·5—78·5	78·5—79·5	79·5—80·5	80·5—81·5	81·5—82·5	82·5—83·5	83·5—84·5	84·5—85·5	85·5—86·5	86·5—87·5	87·5—88·5	88·5—89·5	89·5—90·5	90·4—91·5	91·5—92·5	Totals.
62·5—63·5	—	1	—	—	1	—	—	—	·5	1·5	·5	1·5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7
63·5—64·5	1	2	—	1·5	—	—	—	—	—	1	—	1	—	1	—	—	—	—	—	—	—	—	—	·5	—	—	—	—	—	—	8
64·5—65·5	—	—	1	1·5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	·5	—	—	—	—	—	—	4
65·5—66·5	—	1·5	1·5	—	—	—	—	—	1	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6
66·5—67·5	1	—	1	—	—	—	—	2	—	1	2	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9
67·5—68·5	—	—	—	—	—	1	·5	—	—	—	1	—	·5	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
68·5—69·5	—	—	—	—	—	·5	2	2	—	—	2	—	·5	1	1	1	—	—	1	—	1	—	—	—	—	—	—	—	—	—	12
69·5—70·5	—	—	—	—	2	—	2	2	1	2·5	2	4·5	2	1	2	3	·5	1	1	2	—	—	—	—	—	—	—	—	—	—	28·5
70·5—71·5	·5	—	—	1	—	—	—	1	4	4	1·25	2·75	2	—	1	3	·5	—	—	—	—	—	—	—	—	—	—	—	—	—	21
71·5—72·5	1·5	1	—	—	1	—	—	2·5	4	4	4·75	4·75	6	9	2	5	·5	2	—	—	2	—	—	—	—	—	—	—	—	—	50
72·5—73·5	·5	—	—	1	2	1	2	2	1·25	4·75	2	3	1·5	8·5	9	4	6·5	1·5	2	4	1	—	—	1	1	—	—	—	—	—	59·5
73·5—74·5	1·5	1	—	—	1	—	—	4·5	2·75	4·75	3	10	12	10·5	4·25	5·75	1·5	1·5	·5	3	—	—	1	—	—	—	—	—	—	—	68·5
74·5—75·5	1	—	—	1	—	·5	·5	2	2	6	1·5	12	14	14·5	6·25	11·75	11	4	2·5	3	1	2	—	—	—	—	—	—	—	—	96·5
75·5—76·5	—	1	—	—	1	1	1	1	—	9	8·5	10·5	14·5	21	26	16·5	18	8·5	8·5	9	5	1·5	—	—	—	—	—	—	—	—	161·5
76·5—77·5	—	—	—	—	—	1	1	2	1	2	9	4·25	6·25	26	27	16·5	34·5	21·5	14	15	6·5	1	1	—	—	—	—	—	—	1	190·5
77·5—78·5	—	—	—	—	—	—	1	3	3	5	4	5·75	11·75	16·5	16·5	43	29	25·5	27·5	18·75	6·25	4	1	3·25	1·25	—	—	—	—	—	226
78·5—79·5	—	—	—	—	—	—	—	·5	·5	·5	6·5	1·5	11	18	34·5	29	42	31·5	16·5	16·25	11·25	9·5	1·5	·25	·25	—	—	—	—	—	231
79·5—80·5	—	—	—	—	—	—	—	1	—	2	1·5	1·5	4	8·5	21·5	25·5	31·5	37	13·75	22·25	17	4	11	—	2	1	—	—	—	—	205
80·5—81·5	—	—	—	—	—	—	1	1	—	—	2	·5	2·5	8·5	14	27·5	16·5	13·75	32·5	19·25	9	7·5	6·5	2·5	—	—	—	·5	·5	·5	166
81·5—82·5	—	—	—	—	—	—	—	2	—	—	4	3	3	9	15	18·75	16·25	22·25	19·25	23	6	6·5	6·5	3	—	1	—	·5	—	—	159
82·5—83·5	—	—	—	—	—	—	1	—	—	2	1	—	1	5	6·5	6·25	11·25	17	9	6	8	5	3·5	3	1	—	—	—	—	·5	87
83·5—84·5	—	—	—	—	—	—	—	—	—	—	—	—	2	1·5	1	4	9·5	4	7·5	6·5	5	3	1·5	3	—	2	1	—	—	·5	52
84·5—85·5	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	1	1·5	11	6·5	6·5	3·5	1·5	2	2	1	1	1	—	—	1	41·5
85·5—86·5	—	·5	·5	—	—	—	—	—	—	—	1	—	—	—	—	3·25	·25	—	2·5	3	3	3	2	2	—	—	—	—	1	—	22
86·5—87·5	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1·25	·25	2	—	—	1	—	1	—	—	—	—	—	—	—	6·5
87·5—88·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	2	1	—	—	—	—	—	—	—	5
88·5—89·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	2
89·5—90·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	·5	·5	—	—	—	—	—	—	—	—	—	—	1
90·5—91·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	·5	—	—	—	—	1	—	—	—	—	—	—	1·5
91·5—92·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	·5	—	·5	·5	1	—	—	—	—	—	—	—	3·5
Totals ...	7	8	4	6	9	5	12	28·5	21	50	59·5	68·5	96·5	161·5	190·5	226	231	205	166	159	87	52	41·5	22	6·5	5	2	1	1·5	3·5	1936

E (iii).

Cephalic Index. Brother-Sister.

Brother.

Sister.	*70—71*	*71—72*	*72—73*	*73—74*	*74—75*	*75—76*	*76—77*	*77—78*	*78—79*	*79—80*	*80—81*	*81—82*	*82—83*	*83—84*	*84—85*	*85—86*	*86—87*	*87—88*	*88—89*	*89—90*	*90—91*	Totals.
68—69	—	—	—	—	·5	·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
69—70	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
70—71	—	—	—	1	—	—	—	·5	2	—	—	—	—	—	—	—	—	—	—	—	—	3·5
71—72	—	1	—	1	2	3	3	1	·5	—	—	—	—	—	—	—	—	—	—	—	—	11·5
72—73	—	—	1	4	—	1	3	1·5	1·5	—	1	—	—	—	—	—	—	—	—	—	—	13
73—74	1	—	2	4·5	—	2	·5	2	—	—	—	2	—	—	—	—	—	—	—	—	—	14
74—75	—	1·5	·5	4·5	3	4	7	3	4	4	2	—	2	—	·5	—	—	—	—	—	—	36
75—76	—	2·5	·5	2·5	4	6·5	7	4	8·25	6·25	5	1·5	1·5	1	·5	—	—	—	—	—	—	51
76—77	·5	—	4·5	2·5	3	6·5	11·25	9	8·75	10	9	3	1	—	—	1	—	—	—	—	—	70
77—78	·5	1	1·5	2	5	13·5	7·75	12	14·5	3·25	4·25	3·25	3·5	1·5	—	1	—	—	—	—	—	74·5
78—79	1	1	—	3·5	4	7·5	10·5	16·5	14	14·5	12·25	6·75	5·5	4·5	3	1	—	1	—	—	—	106·5
79—80	1	—	—	1	1·5	5	5·5	10	18·5	10	9	7	5·5	6	1	1	1	1	—	—	—	84
80—81	—	—	1	3	1·5	2	2·5	9·5	14	13·25	12·25	10·5	4·5	2·5	2	2	1	—	—	—	—	81·5
81—82	—	—	—	—	1	2	3·5	6·5	8	6·75	9·25	3·5	6	3·5	3	—	—	1	—	—	—	54
82—83	—	—	—	1·5	1·5	3	3·5	1·5	7·25	1·75	4·5	6	2	3·5	3	1	1	—	—	—	1	42
83—84	—	—	—	—	2	2·5	3·5	4	2·75	4·75	2	7·5	·5	2	3	·5	1	—	—	—	—	36
84—85	—	—	—	—	1·5	1	·5	1	1·5	4·5	2	3·5	3	—	2	·5	—	—	—	—	—	22
85—86	—	—	—	—	—	—	1	—	—	1	4	2	·5	1	—	—	—	—	1	·5	—	11
86—87	—	—	—	—	—	—	1	—	—	—	—	4	1	—	—	—	1	1	1	·5	—	9·5
87—88	—	—	—	—	—	—	1	—	—	—	—	—	—	1	·5	·5	—	—	—	—	—	3
88—89	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	2
89—90	—	—	—	—	—	—	—	1	—	1	—	—	1	1	—	—	—	—	—	—	—	4
Totals ...	5	7	11	31	30·5	61	73	83	105·5	81	76·5	61·5	37·5	27·5	18·5	8·5	5	4	3	1	1	732

F (i).

Head Length reduced to 12 years. Brother-Brother.

First Brother.

Second Brother.

	163·5	*165·5*	*167·5*	*169·5*	*171·5*	*173·5*	*175·5*	*177·9*	*179·5*	*181·5*	*183·5*	*185·5*	*187·5*	*189·5*	*191·5*	*193·5*	*195·5*	*197·5*	*199·5*	*201·5*	*203·5*	*205·5*	Totals.
163·5	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
165·5	—	—	·5	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	2·5
167·5	—	·5	1	1	—	—	·5	·5	—	—	—	·5	—	—	—	—	—	—	—	—	—	—	4
169·5	1	—	1	2	1·5	4	3	4	1	1	2	1·5	2	—	—	—	—	—	—	—	—	—	24
171·5	—	—	—	1·5	4	5·5	4·5	9·5	2	5	2	3	3	1	1	—	1	1	—	—	—	—	44
173·5	—	—	—	4	5·5	2	5·5	15·5	2·5	6	6·5	3	1·5	—	—	—	1·5	—	—	—	—	—	53·5
175·5	—	—	·5	3	4·5	5·5	7	5	12	18·5	16·5	7·5	4·25	3·75	1	—	·5	1	—	—	—	—	90·5
177·5	1	1	·5	4	9·5	15·5	5	17	24	21	20·5	10·75	8	4·25	4·5	2·5	—	1	—	—	—	—	150
179·5	—	1	—	1	2	2·5	12	24	32	25	29	28·5	15	4·5	5·5	1	2	—	—	—	—	1	186
181·5	—	—	—	1	5	6	18·5	21	25	24	42·5	24·75	24·75	12·25	17·75	4·5	2	1	—	—	—	—	230
183·5	—	—	—	2	2	6·5	16·5	20·5	29	42·5	53·5	35	35·5	19·75	16·75	5·5	4·5	2·5	2·5	1	—	—	295·5
185·5	—	—	·5	1·5	3	3	7·5	10·75	28·5	24·75	35	28·5	31	23·25	24	7·25	4·5	2	1·5	1	—	1	238·5
187·5	—	—	—	2	3	1·5	4·25	8	15	24·75	35·5	31	28	23·75	17·75	13	6·5	2	·5	—	—	1	217·5
189·5	—	—	—	—	1	—	3·75	4·25	4·5	12·25	19·75	23·25	23·75	33	26·75	15·5	9·75	7	4	1	—	—	189·5
191·5	—	—	—	—	1	—	1	4·5	5·5	17·75	16·75	24	17·75	26·75	23	9·75	10·75	4	2	·5	1	—	166
193·5	—	—	—	—	—	—	—	2·5	1	4·5	5·5	7·25	13	15·5	9·75	16	4·5	6	3·5	—	—	—	89
195·5	—	—	—	—	1	1·5	·5	—	2	2	4·5	4·5	6·5	9·75	10·75	4·5	5	5·5	2·5	1	—	—	61·5
197·5	—	—	—	—	1	—	1	1	—	1	2·5	2	2	7	4	6	5·5	3	·5	1·5	—	—	38
199·5	—	—	—	—	—	—	—	—	—	—	2·5	1·5	·5	4	2	3·5	2·5	·5	—	1·5	—	—	18·5
201·5	—	—	—	—	—	—	—	—	—	—	1	1	—	1	·5	—	1	1·5	1·5	—	1	—	8·5
203·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	2
205·5	—	—	—	—	—	—	—	—	1	—	—	1	1	—	—	—	—	—	—	—	—	—	3
Totals	2	2 5	4	24	44	53·5	90·5	150	186	230	295·5	238·5	217·5	189·5	166	89	61·5	38	18·5	8·5	2	3	2114

F (ii).

Head Length reduced to 12 years. Sister-Sister.

First Sister.

Second Sister.	*159·5*	*161·5*	*163·5*	*165·5*	*167·5*	*169·5*	*171·5*	*173·5*	*175·5*	*177·5*	*179·5*	*181·5*	*183·5*	*185·5*	*187·5*	*189·5*	*191·5*	*193·5*	*195·5*	*197·5*	*199·5*	*201·5*	*203·5*	Totals.
159·5	—	—	—	—	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
161·5	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	2
163·5	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	1	—	—	—	—	—	—	3
165·5	—	—	—	5	2·5	3	2	—	4	4	3	1	2·5	·5	—	—	—	—	—	—	—	—	—	27·5
167·5	1	—	—	2·5	2	3·5	4	4	7·5	10	2	1	—	1	—	1	—	1	—	—	—	—	—	40·5
169·5	—	—	—	3	3·5	5	8·25	10·25	3	3	5·5	3	5	·5	3·5	—	—	—	—	—	—	—	—	53·5
171·5	2	—	—	2	4	8·25	21·5	9·25	8·5	13·5	10·5	5·5	7·5	5	1	—	1·5	1	1	—	—	—	—	102
173·5	—	—	—	—	4	10·25	9·25	11	17	22·5	19	10·5	11	5·5	4·5	1·5	·5	·5	—	1	—	—	—	128
175·5	—	—	—	4	7·5	3	8·5	17	38	34	24·5	18	6·5	5·5	4·5	6	—	2	—	—	—	—	—	179
177·5	—	1	—	4	10	3	13·5	22·5	34	25	33·5	38·5	28	15	7	4·5	3	1	—	1	—	—	—	244·5
179·5	—	—	—	3	2	5·5	10·5	19	24·5	33·5	41	36·5	31	20	19	6·5	1	1	1	—	—	—	—	255
181·5	—	—	—	1	1	3	5·5	10·5	18	38·5	36·5	33	32·5	18·5	24	3·5	6	3	5	—	—	—	—	239·5
183·5	—	—	1	2·5	—	5	7·5	11	6·5	28	31	32·5	26	28·5	23·5	10·5	5	2·5	2·5	—	—	—	—	223·5
185·5	—	—	1	·5	1	·5	5	5·5	5·5	15	20	18·5	28·5	23	19	16	4·5	2·5	6	—	1	1	—	174
187·5	—	1	—	—	—	3·5	1	4·5	4·5	7	19	24	23·5	19	15	12·25	5·25	2	3·5	3	2	—	—	150
189·5	—	—	—	—	1	—	—	1·5	6	4·5	6·5	3·5	10·5	16	12·25	15·5	5·25	2·5	1	—	—	—	—	86
191·5	—	—	1	—	—	—	1·5	·5	—	3	1	6	5	4·5	5·25	5·25	2	2	—	—	—	—	—	37
193·5	—	—	—	—	1	—	1	·5	2	1	1	3	2·5	2·5	2	2·5	2	—	—	—	—	·5	·5	22
195·5	—	—	—	—	—	—	1	—	—	—	1	5	2·5	6	3·5	1	—	—	—	1	—	—	—	21
197·5	—	—	—	—	—	—	—	1	—	1	—	—	—	—	3	—	—	—	1	—	—	—	—	6
199·5	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	—	—	—	—	—	—	—	—	3
201·5	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	·5	—	—	—	—	—	1·5
203·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	·5	—	—	—	—	—	·5
Totals	3	2	3	27·5	40·5	53·5	102	128	179	244·5	255	239·5	223·5	174	150	86	37	22	21	6	3	1·5	·5	2002

F (iii).

Head Length reduced to 12 *years. Brother-Sister.*

Brother.

Sister.	*163·5*	*165·5*	*167·5*	*169·5*	*171·5*	*173·5*	*175·5*	*177·5*	*179·5*	*181·5*	*183·5*	*185·5*	*187·5*	*189·5*	*191·5*	*193·5*	*195·5*	*197·5*	*199·5*	*201·5*	*203·5*	*205·5*	Totals.
159·5	—	1	·5	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3·5
161·5	—	·5	·5	—	—	—	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	4
163·5	—	·5	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2·5
165·5	—	1	—	1·75	1·75	2	1	1	1	—	1	—	—	3	—	—	—	—	—	—	—	—	13·5
167·5	—	1	—	·25	2·25	3	1	1	1·5	3·5	4	3	2	—	—	—	—	—	—	—	—	—	22·5
169·5	1	2	1	2	—	—	2	4·5	2·5	4	2	4	1	1	—	—	—	—	1	—	—	—	28
171·5	—	2	—	—	4	3·5	4·5	4·75	1·75	1·5	4·5	4	4·5	—	1	—	—	—	—	—	—	—	36
173·5	—	—	—	·5	3·5	5	4·5	5·75	7·75	9	8	5	4	2·5	2·5	·5	—	—	—	—	1	—	59·5
175·5	—	—	—	1	2	1	6·5	7·5	12·5	16	15·5	9·25	6·75	6	5	2·5	—	—	1	—	—	—	92·5
177·5	—	—	—	·5	1·5	5	3	10	16	11	13	10·75	11·75	12	2	4·5	—	—	—	—	—	—	101
179·5	—	—	—	—	1	4	5	3·5	9·25	18·25	15·5	22	9	9	2·5	4	3	·5	1·5	—	—	1	109
181·5	—	—	—	—	1	2	·5	5	5·75	8·25	16·25	14·75	10·5	11	1·5	1·25	·25	1	1	—	—	—	80
183·5	—	—	—	1	2	1·5	1	5	6·5	7·75	9·5	14·25	9·5	14·5	5	5·25	2·75	·5	—	—	—	—	86
185·5	—	—	—	—	1	2	1	1	4·5	1·75	2·75	12·5	11	9	3·5	4	3	1·5	—	—	—	—	58·5
187·5	—	—	—	—	—	—	—	—	1	1	2·75	3·75	5·5	10	6	3	1·5	1·5	1·5	—	—	—	37·5
189·5	—	—	—	—	—	—	1	—	1	2	2·75	4·25	2	1·5	4	4	1	1	·5	—	—	—	25
191·5	—	—	—	—	1	—	1	—	—	—	1	1	2	3	1	2·5	2·5	4	·5	—	—	—	19·5
193·5	—	—	—	—	1	—	—	1	—	—	—	1	—	1	1	—	—	·5	—	—	—	—	5·5
195·5	—	—	—	—	—	—	—	—	1	1	1	1	—	—	·5	·5	1	1	—	—	—	—	7
197·5	—	—	—	—	—	—	—	—	—	—	1	—	—	2	—	—	—	—	—	—	1	—	4
Totals	1	8	3	7	22	31	32	52	73	86	100·5	110·5	79·5	85·5	35·5	32	15	11·5	7	0	2	1	795

G (i).

Head Breadth reduced to 12 *years.* *Brother-Brother.*

First Brother.

Second Brother.

	122·5	*124·5*	*126·5*	*128·5*	*130·5*	*132·5*	*134·5*	*136·5*	*138·5*	*140·5*	*142·5*	*144·5*	*146·5*	*148·5*	*150·5*	*152·5*	*154·5*	*156·5*	*158·5*	*160·5*	Totals.
122·5	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
124·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
126·5	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
128·5	—	—	—	2	—	2	1	1	—	2	—	—	—	—	—	—	—	—	—	—	8
130·5	—	—	1	—	10	—	1	6	—	2	—	1	1	—	—	—	—	—	—	—	22
132·5	—	—	—	2	—	4	3	9	2	4	—	1	1	—	—	—	—	—	—	—	26
134·5	1	—	—	1	1	3	6	5	9	7	4	3	2	2	1	2	—	—	—	—	47
136·5	—	—	—	1	6	9	5	4	17	11	10	9	9	2	2	1	—	—	—	—	86
138·5	—	—	—	—	—	2	9	17	14	23	23	18	6	5	4	4	1	1	—	—	127
140·5	—	—	—	2	2	4	7	11	23	46	35	36·5	27·5	22	10	1	1	—	—	—	228
142·5	—	—	—	—	—	—	4	10	23	35	36	45	35·5	32	15	8	2	2	—	—	247·5
144·5	—	—	—	—	1	1	3	9	18	36·5	45	50	39·5	33	23·25	13·25	4·5	·5	·5	1	279
146·5	—	—	—	—	1	1	2	9	6	27·5	35·5	39·5	44	43	29·75	28·25	7·5	—	—	—	274
148·5	—	—	—	—	—	—	2	2	5	22	32	33	43	66	37·5	21·5	20	5	—	1	290
150·5	—	—	—	—	—	—	1	2	4	10	15	23·25	29·75	37·5	36	23·5	8·5	10·5	5	1	207
152·5	—	—	—	—	—	—	2	1	4	1	8	13·25	28·25	21·5	23·5	14	11·5	6·5	2	1	137·5
154·5	—	—	—	—	—	—	—	—	1	1	2	4·5	7·5	20	8·5	11·5	8	3	—	4	71
156·5	—	—	—	—	—	—	—	—	1	—	2	·5	—	5	10·5	6·5	3	2	5	—	35·5
158·5	—	—	—	—	—	—	—	—	—	—	—	·5	—	—	5	2	—	5	4	3	19·5
160·5	—	—	—	—	—	—	—	—	—	—	—	1	—	1	1	1	4	—	3	2	13
Totals	1	0	1	8	22	26	47	86	127	228	247·5	279	274	290	207	137·5	71	35·5	19·5	13	2120

G (ii).

Head Breadth reduced to 12 years. Sister-Sister.

First Sister.

Second Sister.	113·5	115·5	117·5	119·5	121·5	123·5	125·5	127·5	129·5	131·5	133·5	135·5	137·5	139·5	141·5	143·5	145·5	147·5	149·5	151·5	153·5	155·5	157·5	159·5	161·5	Totals.
113·5	—	—	—	1	—	—	—	—	·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·5
115·5	—	—	—	1	—	1	—	—	·5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3·5
117·5	—	—	—	1	1	1	—	—	—	·5	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	4·5
119·5	1	1	1	—	1	1	1	—	—	4·5	1	·5	2	—	1	—	—	—	—	—	—	—	—	—	—	15
121·5	—	—	1	1	4	1	1	—	2	—	2·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12·5
123·5	—	1	1	1	1	—	·5	2·5	2·5	1	1·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12
125·5	—	—	—	1	1	·5	4	3·5	1	2	1·5	·75	·25	2	—	—	1	—	—	—	—	—	—	—	—	18·5
127·5	—	—	—	—	—	2·5	3·5	—	1	4	2·5	3·25	2·25	1	—	—	—	—	—	—	—	—	—	—	—	20
129·5	·5	·5	—	—	2	2·5	1	1	5	6	7·5	3·5	4	4·5	2	2	2·5	1·5	1	—	—	—	—	—	—	47
131·5	—	1	·5	4·5	—	1	2	4	6	16	12	8·75	7·75	9	5·5	5·5	3·5	1·5	—	—	—	—	—	—	—	88·5
133·5	—	—	—	1	2·5	1·5	1·5	2·5	7·5	12	11·5	9·75	15·25	9·75	11·75	8	1	1	2	·5	—	—	—	—	—	99
135·5	—	—	—	·5	—	—	·75	3·25	3·5	8·75	9·75	13·5	21·5	21·75	9·75	15·5	5	3	·5	·5	—	—	—	—	—	117·5
137·5	—	—	—	2	—	—	·25	2·25	4	7·75	15·25	21·5	61	36·5	27·75	23·75	8·5	4	1·5	1	—	—	—	—	—	217
139·5	—	—	—	—	—	—	2	1	4·5	9	9·75	21·75	36·5	34	41	38·5	17·5	19	2·5	1	1	—	—	—	—	239
141·5	—	—	1	1	—	—	—	—	2	5·5	11·75	9·75	27·75	41	41·5	41·75	28·5	25	10·5	2	1	·5	—	—	—	250·5
143·5	—	—	—	—	—	—	—	—	2	5·5	8	15·5	23·75	38·5	41·75	50	28	31·5	16·25	4·25	2	—	1	—	—	268
145·5	—	—	—	—	—	—	1	—	2·5	3·5	1	5	8·5	17·5	28·5	28	23	29	15·75	6·25	2·25	1·25	—	1	—	174
147·5	—	—	—	—	—	—	—	—	1·5	1·5	1	3	4	19	25	31·5	29	18	11	6	1·25	·25	—	—	—	152
149·5	—	—	—	—	—	—	—	—	1	—	2	·5	1·5	2·5	10·5	16·25	15·75	11	6	4·5	6	·5	2	1	—	81
151·5	—	—	—	—	—	—	—	—	—	—	·5	·5	1	1	2	4·25	6·25	6	4·5	1	3	·5	—	—	—	30·5
153·5	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	2	2·25	1·25	6	3	1	·5	—	—	1	19
155·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	·5	—	1·25	·25	·5	·5	·5	—	—	—	—	3·5
157·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2	—	—	—	—	—	—	3
159·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	2
161·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Totals	1·5	3·5	4·5	15	12·5	12	18·5	20	47	88·5	99	117·5	217	239	250·5	268	174	152	81	30·5	19	3·5	3	2	1	1880

G (iii).

Head Breadth reduced to 12 *years.* *Brother-Sister.*

Brother.

Sister.

	122·5	124·5	126·5	128·5	130·5	132·5	134·5	136·5	138·5	140·5	142·6	144·5	146·5	148·5	150·5	152·5	154·5	156·5	158·5	160·5	Totals.
121·5	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
123·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
125·5	1	—	—	3	—	1	1	1	2	—	—	—	—	—	—	—	—	—	—	—	9
127·5	1	—	—	1	1	1	—	1	·5	—	—	—	1	—	—	—	—	—	—	—	6·5
129·5	—	—	—	1	—	—	5·5	2	1·5	2·5	1	2·5	2	·5	—	—	—	—	—	—	18·5
131·5	—	—	—	·5	—	1	1·5	3	5	7·5	·5	4	1	2·5	—	1	1	1	—	—	29·5
133·5	—	—	—	1	·5	—	9	2·5	9	6	7·5	1·5	3	3	—	—	—	—	—	—	43
135·5	—	—	—	—	1	3	4	6·5	9·5	7·5	8·5	9·5	8·5	2	—	1	—	—	—	—	61
137·5	—	—	—	—	·5	1	4·5	11	8·5	15·5	15	12	8	11·5	2	2	1·5	—	—	—	93
139·5	—	—	—	—	1·5	—	2·5	2·5	7·5	15·5	23	19·5	17	4·5	6·25	4·25	·5	—	1	—	105·5
141·5	—	—	—	1	—	—	—	5·5	8	12·5	21	22	13·5	10	11·25	4·25	2·5	—	—	—	111·5
143·5	—	—	—	·5	1·5	—	2	3·5	5	12·5	10·5	5	9	18	10·5	5	4	1	—	1	89
145·5	—	—	—	—	—	—	—	·5	1	7·5	8	6	14	11	11·5	7·5	4·5	1	4	—	76·5
147·5	—	—	—	—	—	—	—	—	3	2	3·5	4	6·5	14·5	13	5	5	3	1	—	60·5
149·5	—	—	—	—	—	1	—	—	1	·5	1	2	4	7·25	4·25	2·5	1	2	·5	1	28
151·5	—	—	—	—	—	—	—	—	—	—	—	2·5	2	1·25	3·25	·5	2	2	1·5	—	15
153·5	—	—	—	—	—	—	—	—	—	1	—	·5	1	—	1·5	2	1	—	—	—	7
155·5	—	—	—	—	—	—	—	—	—	—	—	1	—	—	·5	—	—	—	—	1	2·5
157·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	·5	—	—	—	—	·5
159·5	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	·5	—	—	—	—	1·5
Totals ...	2	0	0	8	6	8	30	40	61·5	91·5	99·5	92	90·5	86	64	36	23	10	8	3	759

H (i).

Head Height reduced to 12 years. Brother-Brother.

First Brother.

Second Brother.	*104·5*	*106·5*	*108·5*	*110·5*	*112·5*	*114·5*	*116·5*	*118·5*	*120·5*	*122·5*	*124·5*	*126·5*	*128·5*	*130·5*	*132·5*	*134·5*	*136·5*	*138·5*	*140·5*	*142·5*	*144·5*	*146·5*	Totals.
104·5	—	—	·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	·5
106·5	—	—	·5	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	2·5
108·5	·5	·5	—	—	—	—	1	·5	·5	—	—	—	1	—	—	—	—	—	—	—	—	—	4
110·5	—	—	—	1	·5	·5	2	1·5	3·5	·5	1	1	—	—	—	—	—	—	—	—	—	—	11·5
112·5	—	—	—	·5	2	—	2	1	3·5	·5	—	—	1	1	—	—	—	—	—	—	—	—	11·5
114·5	—	—	—	·5	—	2	8·75	4·25	3	4·25	4·25	1	—	·5	1	1	—	·5	—	—	—	—	31
116·5	—	—	1	2	2	8·75	8·5	14·25	10·5	8	8	5	6	4	1·5	·5	1	·5	—	1	—	—	82·5
118·5	—	1	·5	1·5	1	4·25	14·25	17	17	16·25	17·25	15	7	8	3	1·5	—	1	—	—	—	—	125·5
120·5	—	—	·5	3·5	3·5	3	10·5	17	11	20·75	20·75	18·5	13·75	9·25	6·5	4·25	1·25	·5	—	—	—	—	144·5
122·5	—	—	—	·5	·5	4·25	8	16·25	20·75	20·5	26	28·5	20	13·25	8·5	3·5	6	·5	3·5	1	—	—	181·5
124·5	—	—	—	1	—	4·25	8	17·25	20·75	26	33	39·5	31	20·25	13	10·25	3·75	1·5	1·5	2	—	—	233
126·5	—	1	—	1	—	1	5	15	18·5	28·5	39·5	40	37·5	37	26·75	14·75	3	2·5	2	—	—	1	274
128·5	—	—	1	—	1	—	6	7	13·75	20	31	37·5	27	31·25	26·75	12·75	14	3·5	2·5	1·5	—	—	236·5
130·5	—	—	—	—	1	·5	4	8	9·25	13·25	20·25	37	31·25	48	30·75	16·75	13	11·5	5·5	1·5	2	—	253·5
132·5	—	—	—	—	—	1	1·5	3	6·5	8·5	13	26·75	26·75	30·75	23	14·75	11·75	7·25	7·5	1·5	1	1	185·5
134·5	—	—	—	—	—	1	·5	1·5	4·25	3·5	10·25	14·75	12·75	16·75	14·75	10·5	12·25	8·25	5·5	·5	2	—	119
136·5	—	—	—	—	—	—	1	—	1·25	6	3·75	3	14	13	11·75	12·25	9	5·5	6·5	1·25	1·25	—	89·5
138·5	—	—	—	—	—	·5	·5	1	·5	·5	1·5	2·5	3·5	11·57	7·25	8·25	5·5	7	3·5	3·25	1·25	—	58
140·5	—	—	—	—	—	—	—	—	—	3·5	1·5	2	2·5	5·5	7·5	5·5	6·5	3·5	3	—	1	1	43
142·5	—	—	—	—	—	—	1	—	—	1	2	—	1·5	1·5	1·5	·5	1·25	3·25	—	2	—	—	15·5
144·5	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	2	1 25	1·25	1	—	—	—	8·5
146·5	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	1	—	—	—	3
Totals	·5	2·5	4	11·5	11·5	31	82·5	125	144·5	181·5	233	274	236·5	253·5	185·5	119	89·5	58	43	15·5	8·5	3	2114

H (ii).

Head Height reduced to 12 years. *Sister-Sister.*

First Sister.

Second Sister.	*104·5*	*106·5*	*108·5*	*110·5*	*112·5*	*114·5*	*116·5*	*118·5*	*120·5*	*122·5*	*124·5*	*126·5*	*128·5*	*130·5*	*132·5*	*134·5*	*136·5*	*138·5*	*140·5*	*142·5*	*144·5*	*146·5*	Totals.
104·5	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	2
106·5	—	—	1	—	—	3	—	—	2	—	1	—	1	—	—	—	—	—	—	—	—	—	8
108·5	—	1	6	—	2	2	5	3	3	—	—	1	—	1	—	—	—	—	—	—	—	—	24
110·5	—	—	—	6	—	8	6·5	4·5	3·5	3	1	1	—	—	—	—	—	—	—	—	—	—	33·5
112·5	—	—	2	—	2	8	3	4	4·5	4·5	5	1	—	—	—	—	—	—	—	—	—	—	34
114·5	—	3	2	8	8	10	16	12	8·5	11	7	3	—	—	2	2	—	—	—	—	—	—	92·5
116·5	—	—	5	6·5	3	16	20	9·5	11·5	9	13·5	3	2	1	3	1	—	1	—	—	—	—	105
118·5	1	—	3	4·5	4	12	9·5	9	19	27	17·5	14	10	6	1	3	2	1	—	—	—	—	143·5
120·5	1	2	3	3·5	4·5	8·5	11·5	19	32	41·5	20·5	23	11	14	2	7	3	—	2	—	—	—	209
122·5	—	—	—	3	4·5	11	9	27	41·5	31	37·5	23	21	11	7	2	3	—	1	2	1	—	235·5
124·5	—	1	—	1	5	7	13·5	17·5	20·5	37·5	35	29·5	22·5	13·5	8·5	5	5	4	1	—	—	—	227
126·5	—	—	1	1	1	3	3	14	23	23	29·5	28	21·5	12·5	14	9	2	4	2	—	—	—	191·5
128·5	—	1	—	—	—	—	2	10	11	21	22·5	21·5	38	19	11	7	3	—	—	1	—	—	168
130·5	—	—	1	—	—	—	1	6	14	11	13·5	12·5	19	12	11	11	3	1	2	1	1	—	120
132·5	—	—	—	—	—	2	3	1	2	7	8·5	14	11	11	10	5	2	1	4	1	—	1	83·5
134·5	—	—	—	—	—	2	1	3	7	2	5	9	7	11	5	12	3	3	3	1	—	—	74
136·5	—	—	—	—	—	—	—	2	3	3	5	2	3	3	2	3	6	—	—	1	1	—	34
138·5	—	—	—	—	—	—	1	1	—	—	4	4	—	1	1	3	—	2	3	1	—	—	21
140·5	—	—	—	—	—	—	—	—	2	1	1	2	—	2	4	3	—	3	—	2	2	—	22
142·5	—	—	—	—	—	—	—	—	—	2	—	—	1	1	1	1	1	1	2	—	1	—	11
144·5	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	1	—	2	1	—	—	6
146·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
Totals	2	8	24	33·5	34	92·5	105	143·5	209	235·5	227	191·5	168	120	83·5	74	34	21	22	11	6	1	1846

H (iii).

Head Height reduced to 12 years. Brother-Sister.

Brother.

Sister.	*106·5*	*108·5*	*110·5*	*112·5*	*114·5*	*116·5*	*118·5*	*120·5*	*122·5*	*124·5*	*126·5*	*128·5*	*130·5*	*132·5*	*134·5*	*136·5*	*138·5*	*140·5*	*142·5*	*144·5*	*146·5*	*148·5*	*150·5*	*152·5*	Totals.
106·5	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
108·5	1	—	1	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4
110·5	—	1	2	—	1	2	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9
112·5	—	—	—	1	3·5	·5	·5	4·5	2	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	15
114·5	1	—	—	—	4	3	1·5	5	6·75	2·25	3·5	·5	—	—	—	—	—	—	—	—	—	—	—	—	27·5
116·5	—	1	1	1	1	—	2	6	2·25	3·75	4·5	5	3	1	—	—	—	1	—	—	—	—	—	1	33·5
118·5	1	—	·5	1·5	—	4·5	4	5	6	5	3	6	4	5	1	—	2·5	1	—	—	—	—	—	—	50
120·5	—	—	·5	·5	2	3·5	3	9·5	8	11·5	5·5	8	11·5	2·5	1	1	·5	—	—	—	—	1	—	—	69·5
122·5	—	—	—	1	2·5	3	5·5	13·5	13·5	13	12	11	10·5	4	4	4	2	3	1	—	—	—	—	—	103·5
124·5	—	—	—	2	—	2	8	8	11·5	11	16	10	14	5	7·5	6	·5	2·5	1·5	·5	—	—	—	—	106
126·5	—	—	—	—	1	2	3·5	4·5	6·5	13·5	21	12	16	12	2	3	1	1	2	—	—	—	—	—	101
128·5	—	—	—	—	1	1	3	2	1	4·5	10·5	12	15·5	12·5	5	6	2	7	1	·5	·5	—	—	—	85
130·5	—	—	—	—	—	—	—	1	2	3	6	10	9	7·5	3	5·5	1	2·5	·5	1	—	—	—	—	52
132·5	—	—	—	—	—	1	—	1	1	3·5	3·5	4·5	6·5	7	5	3	1	—	2·5	2·5	—	—	—	—	42
134·5	—	—	—	—	—	—	—	—	—	4	3	6	5	6	2	—	4·5	1·5	2	—	—	—	—	—	34
136·5	—	—	—	—	—	—	—	—	—	1·5	2·5	1	1	1	—	1	1	—	1	—	—	—	—	—	10
138·5	—	—	—	—	—	—	—	1	—	1	—	1	1	1	1·5	·5	3	1	1	—	—	—	—	—	12
140·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	2
142·5	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	2	—	—	—	—	—	4
144·5	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	2
Totals	3	3	5	10	16	22·5	32	61	61·5	81·5	91	88	98	65·5	33	30	19	22·5	14·5	4·5	·5	1	0	1	764

ATHLETIC CAPACITY.

I (i).

Brother-Brother.

First Brother.

Second Brother.	Athletic.	Betwixt.	Non-athletic.	Totals.
Athletic	906	20	140	1066
Betwixt	20	76	9	105
Non-athletic	140	9	370	519
Totals	1066	105	519	1690

I (ii).

Sister-Sister.

First Sister.

Second Sister.	Athletic.	Betwixt.	Non-athletic.	Totals.
Athletic	638	15	153	806
Betwixt	15	16	11	42
Non-athletic	153	11	452	616
Totals	806	42	616	1464

I (iii).

Brother-Sister.

Brother.

Sister.	Athletic.	Betwixt.	Non-athletic.	Totals.
Athletic	195	5	43	243
Betwixt	5	2	2	9
Non-athletic	91	5	86	182
Totals	291	12	131	434

II. PSYCHICAL CHARACTERS. DETAILED TABLES.

VIVACITY.

J (i). *Brother-Brother.*

First Brother.

Second Brother.		Quiet.	Noisy.	Totals.
	Quiet	917	292·5	1209·5
	Noisy	292·5	350	642·5
	Totals	1209·5	642·5	1852

J (ii). *Sister-Sister.*

First Sister.

Second Sister.		Quiet.	Noisy.	Totals.
	Quiet	1013	349	1362
	Noisy	349	393	742
	Totals	1362	742	2104

J (iii). *Brother-Sister.*

Brother.

Sister.		Quiet.	Noisy.	Totals.
	Quiet	360·25	164·25	524·5
	Noisy	79·25	148·25	227·5
	Totals	439·5	312·5	752

ASSERTIVENESS.

K (i).

Brother-Brother.

First Brother.

Second Brother.

	Shy.	Self-assertive.	Totals.
Shy	679	247	926
Self-assertive	247	399	646
Totals	926	646	1572

K (ii).

Sister-Sister.

First Sister.

Second Sister.

	Shy.	Self-assertive.	Totals.
Shy	672	296	968
Self-assertive	296	436	732
Totals	968	732	1700

K (iii).

Brother-Sister.

Brother.

Sister.

	Shy.	Self-assertive.	Totals.
Shy	241	114	355
Self-assertive	70·5	147·5	218
Totals	311·5	261·5	573

L (i).

INTROSPECTION.

Brother-Brother.

First Brother.

		Self-conscious.	Unself-conscious.	Totals.
Second Brother.	Self-conscious	600	245	845
	Unself-conscious ...	245	550	795
	Totals	845	795	1640

L (ii).

Sister-Sister.

First Sister.

		Self-conscious.	Unself-conscious.	Totals.
Second Sister.	Self-conscious	561	302·5	863·5
	Unself-conscious ...	302·5	588	890·5
	Totals	863·5	890·5	1754

L (iii).

Brother-Sister.

Brother.

		Self-conscious.	Unself-conscious.	Totals.
Sister.	Self-conscious	126·25	210·25	336·5
	Unself-conscious ...	253·75	66·75	320·5
	Totals	380	277	657

POPULARITY.

M (i). *Brother-Brother.*

First Brother.

		Popular.	Unpopular.	Totals.
Second Brother.	Popular…	1107·5	185·5	1293
	Unpopular	185·5	147·5	333
	Totals	1293	333	1626

M (ii). *Sister-Sister.*

First Sister.

		Popular.	Unpopular.	Totals.
Second Sister.	Popular…	1133·5	182·5	1316
	Unpopular	182·5	175·5	358
	Totals	1316	358	1674

M (iii). *Brother-Sister.*

Brother.

		Popular.	Unpopular.	Totals.
Sister.	Popular…	432·75	54·25	487
	Unpopular	40·75	26·25	67
	Totals	473·5	80·5	554

CONSCIENTIOUSNESS.

N (i).

Brother-Brother.

First Brother.

		Keen.	Dull.	Totals.
Second Brother.	Keen	970	216·5	1186·5
	Dull	216·5	287	503·5
	Totals	1186·5	503·5	1690

N (ii).

Sister-Sister.

First Sister.

		Keen.	Dull.	Totals.
Second Sister.	Keen	1071·5	201	1272·5
	Dull	201	278·5	479·5
	Totals	1272·5	479·5	1752

N (iii).

Brother-Sister.

Brother.

		Keen.	Dull.	Totals.
Sister.	Keen	366·75	122·75	489·5
	Dull	59·75	136·75	196·5
	Totals	426·5	259·5	686

TEMPER.

O (i). *Brother-Brother.*

First Brother.

Second Brother	Quick.	Good-natured.	Sullen.	Totals.
Quick	138·5	152·25	39·75	330·5
Good-natured ...	152·25	1026·5	106·25	1285
Sullen	39·75	106·25	84·5	230·5
Totals	330·5	1285	230·5	1846

O (ii). *Sister-Sister.*

First Sister.

Second Sister.	Quick.	Good-natured.	Sullen.	Totals.
Quick	198	177	77	452
Good-natured ...	177	996	165	1338
Sullen	77	165	120	362
Totals	452	1338	362	2152

O (iii). *Brother-Sister.*

Brother.

Sister.	Quick.	Good-natured.	Sullen.	Totals.
Quick	60	45·5	10	115·5
Good-natured ...	68·75	388	43·75	500·5
Sullen	13·25	56·5	18·25	88
Totals	142	490	72	704

ABILITY.

P (i). *Brother-Brother.*

First Brother.

		Quick-intelligent.	Intelligent.	Slow-intelligent.	Slow.	Slow-dull.	Very dull.	Totals.
Second Brother.	Quick-intelligent	88	62·25	42·25	11	2	2	207·5
	Intelligent	62·25	313·5	183·75	72·5	9·5	1	642·5
	Slow-intelligent	42·25	183·75	255·5	73	22·5	8	585
	Slow	11	72·5	73	97·5	39	4	297
	Slow-dull....	2	9·5	22·5	39	28	7	108
	Very dull.... ...	2	1	8	4	7	6	28
	Totals	207·5	642·5	585	297	108	28	1868

P (ii). *Sister-Sister.*

First Sister.

		Quick-intelligent.	Intelligent.	Slow-intelligent.	Slow.	Slow-dull.	Very dull.	Totals.
Second Sister.	Quick-intelligent	118	111	49·5	14	7	1	300·5
	Intelligent	111	326	213	47	10	5	712
	Slow-intelligent	49·5	213	204	99·5	30	9	605
	Slow	14	47	99·5	64	29	7	260·5
	Slow-dull.... ...	7	10	30	29	22	5	103
	Very dull....	1	5	9	7	5	6	33
	Totals....	300·5	712	605	260·5	103	33	2014

P (iii). *Brother-Sister.*

Brother.

		Quick-intelligent.	Intelligent.	Slow-intelligent.	Slow.	Slow-dull.	Very dull.	Totals.
Sister.	Quick-intelligent	53	39	23	8	5·25	·25	128·5
	Intelligent	51	118·5	90	25	11·75	5·75	302
	Slow-intelligent	17	77·5	119	39	15	5	272·5
	Slow	7	28	38	29	7	1	110
	Slow-dull....	2	5	5	5	9	5	31
	Very dull....	1	3	5	—	1	6	16
	Totals....	131	271	280	106	49	23	860

HANDWRITING.

Q (i).

Brother-Brother.

First Brother.

Second Brother.	Very good.	Good.	Moderate.	Poor.	Bad.	Very bad.	Totals.
Very good	52	51	27·5	3	1	—	134·5
Good	51	335	224·5	32	4	1	647·5
Moderate	27·5	224·5	406	101·5	15·5	2	777
Poor	3	32	101·5	96	15	2	249·5
Bad	1	4	15·5	15	7	1	43·5
Very bad	—	1	2	2	1	4	10
Totals	134·5	647·5	777	249·5	43·5	10	1862

Q (ii).

Sister-Sister.

First Sister.

Second Sister.	Very good.	Good.	Moderate.	Poor.	Bad.	Very bad.	Totals.
Very good	50	29	23	5	—	—	107
Good	29	334	170	36·5	6	—	575·5
Moderate	23	170	300	90·5	17	5	605·5
Poor	5	36·5	90·5	68	14	—	214
Bad	—	6	17	14	10	4	51
Very bad	—	—	5	—	4	4	13
Totals	107	575·5	605·5	214	51	13	1566

Q (iii).

Brother and Sister.

Brother.

Sister.	Very good.	Good.	Moderate.	Poor.	Bad.	Very bad.	Totals.
Very good	15	13	7	3	—	—	38
Good	27	146·5	106·75	31·75	1	—	313
Moderate	9	74	140·25	42·75	—	1	274
Poor	—	13	40	31	4	2	90
Bad	—	2	5	2	2	—	11
Very bad	—	—	1	—	1	—	2
Totals	51	248·5	300	110·5	15	3	728

A STUDY OF THE VARIATION AND CORRELATION OF THE HUMAN SKULL, WITH SPECIAL REFERENCE TO ENGLISH CRANIA.

BY W. R. MACDONELL, LL.D.

(1) *Introductory.*

THE following paper is a contribution to the investigation which has been going on for several years at University College, London, under the direction of Professor Karl Pearson, with the view of determining the size, variability, and correlation of various organs and characters in man. Professor G. D. Thane, head of the Anatomical Department in the college, is the fortunate possessor of a collection of human skulls which were discovered in 1893 in Whitechapel, and it is this great series which forms the subject of my inquiry. We have most heartily to thank Professor Thane for unreservedly placing his splendid material at the disposal of the biometric workers in the college. Some of the skulls had been examined by previous observers, and measurements made of a few of the chief characters, with important results to craniology, but a systematic examination of the whole series had still to be accomplished. At Professor Pearson's suggestion I undertook this very attractive piece of work in 1901, and measured all the skulls in accordance, for the most part, with the system of the *Frankfurter Verständigung*, so far as the condition of the material allowed. In the arithmetical reduction of the measurements I have closely followed the scheme adopted by Cicely D. Fawcett in her great paper on Naqada Crania*. A few of my results will be found to differ a little from those previously published; this is due mainly to the inclusion of several skulls which were not available until towards the very end of the inquiry, and to some final correction of measurements; these discrepancies, however, are not very serious.

(2) *Previous Results for English Skulls.*

These are disappointingly meagre, and a short account of the most important catalogues in which British skulls are described and measured will show the immense relative importance of the Whitechapel series.

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* *Biometrika*, Vol. I. pp. 408—467.

J. Barnard Davis' *Thesaurus Craniorum*, a catalogue of the human skulls in his own collection, published in 1867, deals with the skulls of a great variety of races, but contains no important series of any one race. He divides the races of the British Islands into "Ancient British" and "Modern British"; the former he subdivides into Aboriginal, Ancient Roman, and so on, and of these ancient races he catalogues 85 skulls; the latter he subdivides into English, Welsh, Scottish, and Irish. Of his modern British races he has 135 skulls in all, of which 81 are English, male and female, but for some of these no measurements are given, no doubt owing to the imperfection of the material; and while some are really modern, others are obviously hundreds of years old. Davis, when possible, took 18 measurements on each of his skulls, and if he had possessed a larger and more homogeneous series of English skulls he would have placed extremely valuable material at our disposal for purposes of comparison.

Twelve years after the publication of Davis' *Thesaurus*, Sir William Flower issued Part I. of the Osteological Catalogue of the Royal College of Surgeons, dealing with "Homo Sapiens"; in this work 1018 skulls are catalogued, of which only 278 are European, ancient and modern, and of these 278 only 63 are from the British Isles, and range from "Ancient British" to "Modern." Here again there is practically no material for comparison. One of the most important series in the catalogue appears to be that of 114 modern Italians, mostly males, and as 11 measurements were taken, and 5 indices calculated, on each skull when possible, there is in this case a considerable mass of first-class material ready for reduction *.

No further work of importance on British craniology appears to have been issued in this country until 1903, when Sir William Turner published, in the *Transactions of the Royal Society of Edinburgh* (Vol. XL. Part III. pp. 547—613), a paper on Scottish skulls. This paper contains the measurements of 176 male and female skulls, and is illustrated by photographs: the number of measurements taken on each skull is no less than 33, and 8 indices are calculated, and the mean and maximum and minimum values of each character are given. The great value of the paper as a contribution to craniological literature is obvious, but unfortunately for our purposes, the skulls which it deals with were obtained from different parts of Scotland, and range from quite unknown antiquity to modern specimens from the dissecting rooms; they cannot, therefore, be considered a homogeneous series, and this conclusion is confirmed by an examination of their variability. For example, I find that the standard deviation of the glabello-occipital length in these Scottish skulls is 7·418 for males and 7·151 for females, which shows a much higher variability than is found in fairly contemporary individuals of homogeneous races †. I shall give later in summarising my results the chief biometric constants of Turner's material.

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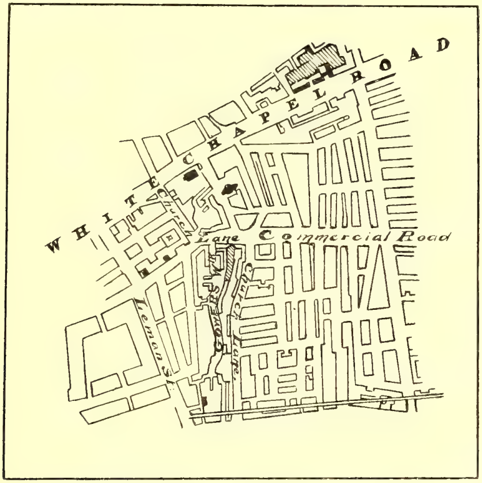
* See, however, Pearson: *Chances of Death*, Vol. I. pp. 332 and 353.

† See *postea*, p. 206, and *Biometrika*, Vol. II. p. 346.

(3) *Material and History of the Site**.

The problems which arise here are far more difficult of solution than appeared on the first discovery of the bones. This took place in the second week of October, 1893, while excavations were being made for the foundations of Kinloch's whiskey stores in Whitechapel. The site lies in a blunt-wedge shaped area bounded at present on the North by Commercial Road, on the West by Gower's Walk, on the East by Backchurch Lane, and on the South by Hooper Street. Kinloch's stores are in Backchurch Lane, a fairly large, new building. Another new building in Gower's Walk, but nearer Hooper Street, is Brown and



Map of site, 1847, before Commercial Road was carried through to the Whitechapel Road. St Mary's is under the "C" of "Whitechapel Road." Under the "n" of the horizontal "Lane" is the hatched area which was Sheen's Burial Ground. Between "r" and "c" of the vertical "Church Lane" on the west is the site of Kinloch's, just above the "nick" or bend at the "c." Hooper Street is not marked, but is an east and west road not quite half the distance below Kinloch's that Kinloch's is from the Commercial Road. The old "Bone Yard" is still visible with a narrow neck running into it the bottom of Gower's Walk. To the west of Leman Street, the large square is Goodman's Fields. These fields existed in the 16th century, extending over the whole district south of St Mary's, and Roman cemeteries were discovered in 1787 in, or perhaps slightly east of, and north of this square.

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* Owing to Dr Macdonell having left London, I have at his request supplied this section. I have to thank Mr Philip Norman, the staff of the Map Department, British Museum, Mr E. M. Borrajo (of the Guildhall Library), Mr M. Apted of Stepney, and Mr W. Minn of Whitechapel for assistance in this inquiry. My demonstrator Mr W. L. Atcherley kindly investigated the distances. K. P.

Eagle's woollen warehouse. The bulk of my informants agree that the bones were found in excavating for Kinloch's; one states that they were found in building Brown and Eagle's. I think there can be no doubt that the site was under Kinloch's, perhaps half-way back to Gower's Walk. Messrs E. R. Barton and W. H. Peile, who drew up a report at the time and saw the bones *in situ*, state that about 150 to 200 yards down Gower's Walk was a hoarding of boards enclosing about an acre of ground between Gower's Walk and Backchurch Lane, "where a number of houses had been pulled down and excavations commenced for the purpose of laying the foundations of [*blank left*]." The length of Gower's Walk to Hooper Street from Commercial Road is 299 yards and Brown and Eagle's is situated at the bottom, or corner of Hooper Street. Kinloch's building is a little less than 200 yards down Backchurch Lane from Commercial Road. I think therefore that there is no doubt about Kinloch's being the actual site.

Turning to the history of the site, I find that the district, now called Goodman's Fields, was originally far more extensive, and in maps of Roman and Anglo-Saxon London is marked with "Roman cemeteries*." Our skulls, however, are certainly not Roman or Romano-British. Further in plans of London from the reign of Queen Elizabeth, "White Chapel" stands in the fields, and between this and Rosemary Lane west of Cable Street there appears to be nothing in the nature of a church or burial-ground, only open country†. In somewhat later plans‡ I find a lane running up through open fields towards the back of St Mary's Church ("White Chapel"). This lane gradually gets more defined; a first piece, "Church Lane," runs from St Mary's Church not quite south, then a piece, Back Church Street, turns at the back of St Mary's west and east, almost where Commercial Road (so-called in 1803, formerly White Horse Lane) now lies, and lastly a long south piece corresponding to the present Backchurch Lane. This string of three portions continues as Church Street, Church Lane, Backchurch Lane, etc., through a whole series of maps and plans, until the real "back church" lane was destroyed when the Commercial Road was carried through into the Whitechapel Road (1865–70), and the two pieces west of St Mary's and east of Gower's Walk became finally Church Lane and Backchurch Lane. Even as late as 1772 we find the space east of Church Lane occupied by fields or closes; for example in "A New Plan of London and Westminster" from Noortbouch's *History of London*. We may therefore assert that Church Lane from St Mary's south to Cable Street became from a field track a definite road about 1658. About the time of the Great Plague we see it on R. Blome's Plan, 1664, with no west enclosures and in Doornech's Plan, 1666, with long horizontal fields to west. A remarkable "Plan des villes de Londres, etc." 1668, shows smaller closes (but no houses) on the west side of Church

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* Darton's Plan of Anglo-Saxon London and Britton's Plan.

† *Londinum, vulgo London*, 1582, and Aggas, 1586, do not extend quite so far; J. Bowles' Plan shows Goodman's Fields stretching east and south of "White Chapel." Rytter, 1604, shows open country. J. Speed, 1610, goes only to the Minories. The "Plan of City of London as fortified by Act of Parliament 1642–3" is not clear but the fortifications seem to cross the site under discussion.

‡ The Lane is not in Walton, 1654, but it is in W. Fairthorne, 1658, and R. Newcourt, 1658.

Lane. If this plan can be trusted, it was absolutely the first spot at which open fields could be reached from Aldgate. It was therefore the very spot most likely to be selected for a pest-field. Now for a short interval at the end of the 17th and beginning of the 18th century the Lane appears running north of "Marine Square" (Wellclose Square), and about half-way down the Lane* on the west side of it (towards what is now Gower's Walk) appears above the nick or bend a small enclosure with apparently two small buildings on it†. This enclosure must have been just where Kinloch's now stands, it may have been a burial-ground or a pest-field with sheds for the pest-carts. It had no existence in the plans of London before the Great Plague; it has disappeared in plans of 1740, while in 1760 we still find fields to the east but houses beginning to the west of the Lane. Finally in 1806 in a *Plan of Cities of London and Westminster* (Lambert's *History of London*) we note Gower's Walk first given by name and a vacant space between this and the houses in Backchurch Lane. Lambert Street, west of Gower's Walk, is given as "Lambe Street" as early as 1742. Thus up to the beginning of 1800 there is no sign of any burial-ground between Backchurch Lane and Gower's Walk. There is, however, as I have already mentioned, a sign of some small enclosure existing in 1688 for a few years. This lasts for about 50 years from the time of the Great Plague (1665–6). We must investigate this a little further. A scale of yards on the plan gives this enclosure between 190 and 200 yards from White Horse Lane—the modern Commercial Road. In other words there is practically not the slightest doubt that Kinloch's is built on the site of this enclosure. If this enclosure had originally been a burial-ground or pest-field, it appears to have lost its significance by 1730, when it ceases to be marked on the new surveys. By 1800 it was built over. We might therefore fairly reasonably assume that burials here of whatever kind would date from the latter half of the 17th century, and most probably from the time of the Great Plague.

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* i.e. half-way from the then "White Horse Lane" (later Commercial Road) which led to "Hangman's Acre," west of Stepney.

† Jean Corvin and C. Mortier, 1688, first give this enclosure above the nick. Of maps between 1665 and 1688, the most important survey, Ogilby's, 1677, stops at the Minories. J. de Ram's Amsterdam map of 1680 gives Church Lane as a straight lane (!), and J. Sellar, 1680, is equally diagrammatic, they indicate fields to west. Later Dutch maps, Jacob de la Feuelle, 1690, Peter van der Aa, 1690, also give no "nick" and the diagrammatic Lane with fields to west. Of maps which show the enclosure I note the following:—R. Morden, P. Lea and C. Browne, 1690; Stridbeck, 1700; Houmann's, ?1700; Lea and Glynne, 1707. Overton's, 1706, shows first a house above nick and his editions give enclosure. John Stowe's map for his survey of 1720 gives this enclosure. I believe this is the last map we can *trust* for the continued existence of the enclosure. It has gone in Rocque's great map of 1735, houses and gardens appearing on the spot. But a whole series of later maps which copy Mortier or Morden and Lea still continue to show it, e.g. Overton, 1731 and 1739; Morden and Lea, 1732; T. Bowles, 1731; John Bowles, 1736; George Foster, 1738; Nürnberg map, 1736; Eliz. Foster, 1752; and even Sayer of 1765! But Rocque of course weighs heavily, as an actual new survey, against all this light material. It is not in T. Taylor, 1723; J. Smith, 1724; or Pine and Tinney, 1744. The "New Survey, London Magazine," 1761, does not show it, but a chain of houses on the west side of Church Lane, and Kitchen and Parker, 1765, show houses beginning to extend round nick. M. Seutter, 1710, shows a triangular-shaped enclosure replacing the irregular quadrilateral of 1688. If correct this was the beginning of the end, but the change escaped John Stowe. Dicey, 1765, shows houses round nick. Marshall, 1782, shows houses at nick, but a gap where Kinloch's now stands; Gower's Walk begins to be visible, looking like a field track. Maps of 1783–1797 show variable but increasing numbers of houses along Church Lane, until in Faden, 1803, we find a continuous belt. Thus between 1730 and 1800 houses sprung up all along the present Backchurch Lane, but the actual site of the supposed pest-field was among the last to be built on.

Turning now to the actual discovery of the bones, we note first that:

(i) No tombstones and coffin furniture were found.

(ii) The skeletons were found scattered with great irregularity, more or less however in rows in shallow trenches. Dr Peile informs me, that he is fairly certain from the manner in which the bones were disposed that they had been placed in position with the flesh upon them.

(iii) The material was very extensive, possibly five to six hundred skeletons.

(iv) Messrs Peile and Barton at first put on one side only those crania of special anatomical interest, but afterwards, the bones having been removed to a railway arch, the whole of the material was procured for scientific study.

(v) The bones were found in made ground, and were said to have been under houses just pulled down, which houses had been built in 1820. If this be so, they must have been originally buried *close* to Backchurch Lane, i.e. where the small enclosure of 1688 existed. Houses, however, certainly existed on the site 20 to 30 years earlier.

(vi) Some of the bones are stained with a green material, looking like salts of copper. No coins except a few Victorian halfpence were admitted by the workmen to have been found.

The conclusion drawn at the time from the evidence then available was that the material had been taken from a plague pit of the 17th century, just a little way from the City gate—Aldgate.

From the standpoint of science it is most heartrending that no proper archaeological enquiry was made at the time. Many points could then have been cleared up which can now be only matter for conjecture.

Now (i) would exclude the idea of a recent burial-ground, although the green stain might possibly be due to "coffin furniture." Some hair was found of various shades, and pieces of what Dr Peile describes as probably "gold lace."

Further (ii) would apparently exclude any removal unless very shortly after interment.

If (v) be certain the bones date from before 1820. In Horwood's map of 1799 houses appear on the site of Kinloch's Stores. Horwood's map also gives a "Bone Yard" at the extreme south of Gower's Walk. Mrs Basil Holmes in her book *The London Burial-Grounds,* 1896, includes (*Appendix,* p. 327) this "Bone Yard, Gower's Walk" among "burial-grounds which have been entirely demolished" for new streets, etc. I suppose she has some authority for supposing this "Bone Yard" to have been a burial-ground, but however this may be, it is entirely away from the site of Kinloch's excavations. She also speaks of "Pest Field or Plague Pit in Gower's Walk now occupied by Messrs Kinloch's new buildings." I presume, however, that she had no better authority for this view than I have given above from Messrs Barton and Peile's report.

I cannot find that on the discovery of the bones any attention was drawn to the existence within a few yards of the spot of a very crowded burial-ground. This forms the real difficulty of the investigation. I first had my attention drawn to it by examining a very recent map of London published by Gall and Inglis. On this map a long strip running south from the Commercial Road about midway between Gower's Walk and Backchurch Lane is marked "Burial-Ground." At present it appears to be a cartage contractor's mews, paved with cobbles, and without the least sign of a burial-ground at all! Measured on Gall and Inglis' map this ground extends about 91 yards south from the Commercial Road. In Crutchley's map of 1847 it is also marked Burial-Ground and extends between 90 and 100 yards from the west and east section of Church Lane, afterwards taken up by the extension of Commercial Road. This enclosure first appears with the name "burial-ground" in Greenwood's fine map of 1824–6. There is no sign of it in any map I have seen from the beginning of the 19th century and still less from the end of the 18th. It is difficult to conceive that it existed before houses were built on Kinloch's site. In Neele's map of 1806 there is a passage across from Gower's Walk to "Church Street," about half-way down to what is now Hooper Street. It is represented now by an alley with squalid cottages running east from Gower's Walk 148 yards down. It does not go through to Backchurch Lane as it did in 1806. This passage would, we hold, have been north of the Kinloch site, and it seems extremely unlikely that the burial-ground should have crossed it, and originally have extended to Kinloch's site. It was some time before I could identify the burial-ground by name. It belonged to an undertaker named Sheen and was called Sheen's Burial-Ground*. In 1829 I find Sheen was living in Leman

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* The cartographic history of Sheen's is the following. We find on the west and east section of Church Lane (now Commercial Road) a "Chapel" and "Burial-Ground" south of it on Greenwood's map of 1824–6. The south end of the ground is 100 to 120 yards from the then Lane. The ground is broader than marked on later maps and more like the present cobbled yard. In Horwood, 1792, there is a close, which obviously became Sheen's. In Bowles of 1786, and his circular map of 1790, there appears to be a house with a garden behind it. Carey, 1787, indicates it too, and I think that this *garden* was Horwood's close which ultimately became Sheen's. It must not be confused with a house and garden—query, chapel and burial-ground—which appear in a very marked way on Laurie and Whittle's map of 1800; Walter, 1801, and possibly Carey, 1766, seem to give this also. It would be west of Sheen's and at the entrance to Great Alie Street. Possibly it was the "Ebenezer Chapel" referred to in a later footnote. In 1823 J. Wyld marks "Chapel" at the spot of chapel on Greenwood, and Thompson, 1823, gives apparently the lines of Sheen's ground. In 1827 Wyld gives the burial-ground unnamed; in 1828, Faden gives "chapel" without ground. In 1826, 1827, 1835 and 1847 Crutchley has "burial-ground." In Faden, Hughes, R. Rowe, Smith, Fores, Darton, Phillips, Mogg, Fairbairn, Langley and Bletch, Luffman, all maps from 1803–1810, it does *not* appear. In Sherwood, Neele and Jones, 1813; Mogg, 1814; Carey, 1818; Leigh, 1820; etc. etc. it is absent. Laurie and Whittle, 1809–10, indicate a dotted close, and Cooke, 1801, a building at the entrance. To sum up, Sheen's as a burial-ground most likely did not exist before 1820 and was probably placed with a chapel on the site of an old house and garden.

Street*, but his business appears afterwards to have been removed to a house near the gate of the ground in Backchurch Lane. Sheen's Burial-Ground was closed April 1, 1854. A witness before the Select Committee on Improvement of Health in Towns in 1842 speaks of it as having been opened "some years ago†." In Chadwick's Report, 1843, it is stated to be 9680 square yards with 600 burials per annum and 300 burials per acre. It was thus a small ground, but if its depth was between 90 and 100 yards, it must have been about 100 yards broad, whereas on the maps after Greenwood it is given as a long thin strip hardly 15 to 20 yards broad. It was thus described by G. A. Walker in his *Gatherings from Grave Yards*, 1839: "This also is a *private* burying-place. The proprietor of this ground is an undertaker. He has planted it with trees and shrubs, which are sufficiently attractive, but the ground is saturated with human putrescence."

Before I leave Walker's terrible survey of the state of the London graveyards in 1839, I must refer to what he terms the "management" of these burial-grounds. Thus he gives on p. 199 an account of a Mile End private burial-ground belonging to an undertaker, where the coffins were dug up, the coffin furniture, nails more especially, sold to "dealers in marine stores," the coffin wood was apparently used as fuel, and the bodies, only interred about a month or six weeks, thrown into a deep hole in an obscure corner of the ground. In this way place was made for fresh interments in the better and more crowded part of the ground. This case was by no means an isolated one. "Management" and "clearance" went on in many of the crowded London graveyards before 1854.

The problem before us then is this: a graveyard (now unrecognised as a cartage contractor's yard) existed some 30 to 50 yards only north of the site where the bones were found. It was densely packed, its southern boundary is not very clearly defined and it appears to have been larger than the marked enclosure of the maps. Could there have existed a clearance pit outside of this graveyard, or could it have extended at some time some distance further south than the maps indicate? If it can now be used as a mews, there is no reason why a portion of it should not have been sold off for building purposes after being filled up in the first half of the nineteenth century. If this had happened our crania would date from 1820 say to 1850. They would belong to the better class of denizens in Whitechapel, i.e. those who could afford to buy a grave and did not exercise their right as parishioners to be buried in St Mary's overcrowded graveyard. It must be remembered that there was a residential population of merchants, commercial men, master-mariners and such like living at that time between the Whitechapel and the Commercial

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* "F. Sheen: Coffin plate chaser and Undertaker, 80 Leman Street." He does not appear in the London Directories before this date.

† There was an "Ebenezer Chapel" at the east corner of Gower's Walk and Backchurch Lane, close on to the spot where Little Ayliff Street (now Little Alie Street) runs into the two. One of my local informants tells me that many interments took place at this Chapel: see preceding footnote. This probably accounts for Mrs Basil Holmes' statement that Sheen's ground was used by the Baptists in Little Alie Street and was then called Mr Brittain's burial-ground, "If so it existed in 1763" (*loc. cit.* p. 327). This was possibly the Ebenezer Chapel ground. There is no sign of Sheen's ground on the maps before 1800.

Roads; that in 1829 captains and merchants met in front of the London Hospital to bargain for cargoes, and that from the "New Road," people still living can remember before 1840 walking across the fields to Stepney. In short, Whitechapel was a residential suburb of the commercial classes and not a place of poor natives and poorer aliens. There is little doubt that our crania even under the hypothesis that they belong to a clearance pit from Sheen's ground would be in bulk English and well-to-do. But is this hypothesis to be accepted? Sheen's ground does not appear to have been long in existence—possibly 1820 to 1854. There is no evidence of its ever having crossed the alley referred to above, and there is no reason to doubt the statement that the bones were exhumed from under houses built in (or before?) 1820. Lastly a most extensive system of almost immediate disinterment must have been carried on to allow of several hundred bodies being found placed as these were. It has been necessary, however, to refer to this matter because in the future someone might have been struck by the proximity of Sheen's ground to the site where our crania were excavated, and considered that this possibility had been overlooked. The fact, however, that Kinloch's Stores coincide with the position of a small enclosure in the maps of 1688 to 1720 seems to suggest that either this enclosure was itself a burial-ground or had been used as a pest-field. In either case we should date our skulls as a 17th century series. The existence of a negress' skull among them is not incompatible with this view, and they would then be fairly typical of the London English of that period. They agree very well on the whole with our second series from Moorfields, but neither seems sufficiently modern to belong to the 19th century; they differ in some respects sensibly from the modern English head.

(4) *Measurements made, and Methods of Measurement.*

The measurements and nomenclature are those of the *Frankfurter Verständigung*, with certain exceptions which will be mentioned below.

I used the craniophor*, scriber, goniometer and blocks with which C. D. Fawcett worked, and which are fully described and illustrated in her paper†. The front block, however, was altered by having a projecting edge of 10 mm. length attached to its front; by this device the *gerade Länge* was always measured from the glabella, as the block was kept clear of the superciliary ridges, and the only part of it in contact with the skull was the projecting edge. Of course 10 mm. were always deducted from the reading on the scale showing the distance between the bases of the blocks.

In addition to these instruments I used callipers with curved arms, like those which Flower figures on page xvi. of his Catalogue, also large and small callipers with straight arms, and a steel tape.

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* It would be an improvement I think if the craniophor were made larger and heavier, so as to have greater stability, and if the pointed clamping rod, by means of a spring or otherwise, could be kept always in contact with the skull; much time was lost in the simple operation of fixing the skull in the horizontal plane, owing to the rod losing its grip and falling down.

† *Biometrika*, Vol. I. pp. 413—415.

The three points by which the horizontal plane was determined were the highest points of the rims of the auricular passages and the under rim of the right eye socket, but in a very few cases, where the right eye was not available, the left eye socket was used.

The various measurements and the methods of making them were fully defined and explained by C. D. Fawcett [*], so that I need only describe them very briefly here; but it is necessary to mention certain points more fully where my procedure differed from hers. I follow the order of her paper.

(*a*) Capacity. My method of measurement is described in the next section.

(*b*) Flower's ophryo-occipital length (*F*).

(*c*) Greatest length from glabella to occiput (*L*).

(*d*) Horizontal length, measured with the blocks, on the craniophor as described above (*L'*).

(*e*) Greatest horizontal breadth of skull (*B*).

(*f*) Least breadth of forehead, from one temporal crest to the other, across the frontal bone (*B'*).

(*g*) Height of skull. My attempts to measure the height in the way recommended by the *Frankfurter Verständigung* never seemed to me satisfactory, and I therefore adopted the method of Broca and the French school, taking the height as the distance from basion to bregma, which is the *Frankfurter Hilfs-Höhe*. Flower and Turner both agree with Broca in measuring their height from basion to bregma (*H*).

(*h*) Auricular height, the vertical height measured on the craniophor perpendicular to the horizontal plane in a line perpendicular to the auricular axis, with the vertical scale and sliding rod of the craniophor (*OH*).

In many skulls, owing to the auricular passages or to the orbits being damaged or destroyed, the horizontal plane, and consequently the auricular height, could not be determined. A "Hilfs-Ohrhöhe," however, was obtained in such cases where one or both auricular passages existed, by putting the skull on the craniophor, bringing the sliding rod down on the skull at a point 2—3 cms. behind the bregma, and reading off the height on the vertical scale. Where both auricular passages existed, I had only to read off the height; but where only one passage remained, the skull was supported on the defective side in what was judged to be a horizontal position before the sliding rod was brought down. Such "Hilfs-Ohrhöhen" are marked (*h*) in the Tables of measurements.

(*i*) Length of skull base, from basion to nasion (*LB*).

(*j*) Horizontal circumference, measured directly above the superciliary ridges and round the most projecting part of the occiput (*U*).

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[*] *Loc. cit.*, pp. 416—418.

(*k*) Sagittal circumference or rather arc, from nasion over the top of the head to opisthion (S).

(*l*) Cross circumference or transverse arc, from the upper rim of one auricular passage to that of the other, over the bregma (Q).

The *Verständigung* measures it in a plane perpendicular to the horizontal plane, about 2—3 cm. behind the coronal suture, or, as Dr E. Schmidt* more accurately defines it, cutting the sagittal suture 2½ cm. behind the bregma; Virchow†, however, appears to have taken the measurement over the bregma, and Turner‡ does the same.

(*m*) Face height. This measurement could not be taken, as no skulls were preserved with mandibles attached.

(*n*) Upper face height, from nasion to alveolar point ($G'H$).

(*o*) Face breadth, from the lower end of one zygomatic maxillary suture to that of the other (GB).

(*p*) Zygomatic breadth, from the outermost point of one zygomatic arch to that of the other (J).

(*q*) Nasal height, from middle of nasion to lowest edge of the pyriform aperture. The lowest edge was sometimes on the right side, sometimes on the left (NH).

(*r*) Nasal breadth—greatest breadth of the pyriform aperture (NB).

(*s*) Breadth of orbit (O_1) for the left (L) and right (R) eyes; the greatest breadth from side to side, wherever found, measuring from inner margin to inner margin.

In taking this measurement, the great difficulty is to determine on what point the arm of the callipers should be placed on the nasal side of the orbit§. I have followed what C. D. Fawcett calls the "geodesic" method, which in practice amounts to this: I follow the curvature of the lower orbital rim to its furthest inward point—but never cross the naso-frontal suture—and measure from that point. I found it convenient to mark the point determined upon with a pencil.

(*t*) Greatest height of orbit (O_2), for both eyes, taken perpendicular to O_1.

(*u*) Length of palate (G_1), from the point of the *spina nasalis posterior* to an imaginary surface tangential to the inner alveolar surfaces of the middle incisors||.

I have also measured this length from the *base* of the spine to the same imaginary surface (G_1').

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* *Anthropologische Methoden*, p. 224.

† See note to paragraph 16 of the *Verständigung*.

‡ "Challenger" Report, Zoology, Part 29, 1884.

§ For a discussion of this difficulty see C. D. Fawcett, *loc. cit.*, pp. 430—431.

|| See C. D. Fawcett's remarks on various ways in which this troublesome measurement has been taken, *loc. cit.*, pp. 429—430.

(*v*) Breadth of palate (G_2), between the alveolar walls at the second molars. Owing to great unevenness of the alveolar walls, I have frequently found this a difficult and unsatisfactory measurement.

(*w*) Profile length, from the basion to the alveolar point (GL).

No skull was found with mandible attached; the mandibles could not therefore be appropriated to their respective crania, nor have they been sexed. All the mandible measurements were kindly taken for me by Marion Radford.

(*x*) Condylar width, greatest width of mandible at condyles, from outside to outside (W_1).

(*y*) Angle width, greatest width of mandible at angles, from outside to outside (W_2).

(*z*) Greatest height of mandible, from lowest median projection, to top of process between middle incisors (h_1).

(*z'*) Distance between *foramina mentalia* (f).

It is unnecessary to specify here the various Indices given in the Tables, as the headings of their respective columns show what they represent. They have been found from the very useful *Index-Tabellen zum anthropometrischen Gebrauche* of Carl M. Fürst (Jena, Verlag von Gustav Fischer, 1902).

There remain only the angles to refer to.

(*aa*) Profile angle (P), measured with the goniometer. The skull is placed on the craniophor, and fixed in the position required for determining the horizontal plane, as explained above; the point of the upper bar of the goniometer is then brought into contact with the nasion, and the point of the lower bar with the alveolar point; the moveable rod of the goniometer is then brought parallel to the line joining the points of the bars by an easy adjustment, and the profile angle read off on the protractor scale.

The angles of the triangle formed by the profile length (GL), the skull basis (LB) and the upper face height ($G'H$), were kindly measured for me by Mary Beeton by placing the sides on the trigonometer made for Professor Pearson by the Cambridge Instrument Company*.

(*bb*) Alveolar angle ($A\angle$), between the lines GL and $G'H$.

(*cc*) Nasial angle ($N\angle$), between $G'H$ and LB.

(*dd*) Basilar angle ($B\angle$), between LB and GL.

(*ee*) Basio-nasal horizontal angle ($\theta_1 = 180^\circ - N\angle - P\angle$).

(*ff*) Basio-alveolar horizontal angle ($\theta_2 = P\angle - A\angle$).

Like C. D. Fawcett, I attach most importance to $A\angle$, $N\angle$, and $B\angle$, owing to the difficulty of ascertaining $P\angle$ and the two subsidiary angles θ_1 and θ_2, which depend on P, to a satisfactory degree of accuracy.

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* See C. D. Fawcett, *loc. cit.*, p. 418.

(5) *On the Determination of the Capacity.*

In determining the capacity of the skulls, I used very hard, dry mustard seed, and my procedure was as follows. Through a tin funnel placed in the foramen magnum, I poured in a quantity of seed enough to fill the cavity about half-full, and then gave it a vigorous shaking, so as to get the seed well into the frontal part of the skull; I then filled up the cavity with more seed, to the rim of the foramen magnum, and shook and tapped; the seed of course flowed away in all directions, and I proceeded to fill up, and shake and tap again. This process went on until I was satisfied that I could get practically no more seed into the skull, but one of the greatest difficulties in the operation was to decide when this point was reached: often, when the skull seemed quite full, a turn of the hand would cause the seed to slip away into some unsuspected empty nook, leaving a vacant space round the foramen magnum. Indeed, in some of the skulls, I doubt if I ever succeeded in quite filling the cerebellar fossae.

The filling process being finished, the seed was poured from the skull into a tin can, and from thence through a funnel into the measuring glasses. I had to use more than one of these, as the largest had a capacity of only 1000 cm.^{3}. The process of shaking and tapping then went on with the glasses as with the skulls, until the subsidence of the seed appeared to come to an end, and the volume was then read off on the scale.

In this way I dealt with the first 31 skulls of the series which were sufficiently well preserved to admit of their capacity being determined, but obviously the process was tedious, as two measuring glasses had to be shaken and tapped for each skull, and it seemed doubtful whether I could obtain a fairly uniform density of seed in the glass measures in a series of operations extending over several weeks. Another doubt also suggested itself—was the density of seed in the skull the same as the density in the glasses?

It then occurred to me to weigh, instead of measuring, the seed contents of each skull, and then reduce the weights to volumes, having ascertained once for all the weight of a known volume of the seed. Accordingly I procured a good balance, capable of weighing up to 1500 grammes, and a copper vessel, with a counterpoise, for holding the seed. The skulls having been filled in the way described above, the contents were emptied into the copper vessel, which was then placed on the scale-pan, and the weight determined.

The relation between weight and volume had next to be found. The obvious course was to find a skull of known capacity, fill it with seed in the same manner as the Whitechapel skulls had been filled, and then weigh the contents. Professor Thane kindly placed at my disposal three "crânes étalons" which had been specially prepared, some years before, for having their capacity measured. They had been sawn horizontally into two pieces, and the inner surface painted with a thin coating of waterproof varnish; the two pieces had then been cemented together again, and the whole made watertight. I filled these skulls several times with seed, through the foramen magnum, and weighed the contents, following the same procedure as in the case of the Whitechapel series; I also filled each of the three skulls with water of known volume, the filling being done twice. Knowing the volume of the water and the weight of the seed, I expected to find a fairly constant relation between the two in the various experiments. The results are exhibited in the following Table:

Capacity of "Crânes Étalons."

Skull α		Skull γ		Skull δ	
cm.^{3} of water	Grammes of seed	cm.^{3} of water	Grammes of seed	cm.^{3} of water	Grammes of seed
1445*	1130·58	1790	1364·97	1375	1052·07
1465	1123·70	1790	1381·31	1385	1058·83
	1127·21		1365·47		1048·44
					1061·43
Mean 1455	1127·16	1790	1370·58	1380	1055·19
Weight of 1000 cm.^{3} seed	774·68		765·69		764·63

This table brings out the difficulties of the investigation very forcibly. In the first place it will be noticed that, even using water, I failed to get quite uniform results for the capacity of skull α; an air-bubble may have formed in the recesses of the skull in the first experiment, or a slight leak may have developed in the second, or I may have made some mistake in filling or in noting the volume of water. Again, greater density of seed, on the average, was produced in skull α than in γ and δ; and in the two latter, although the average density was nearly the same, the density was not uniform in the various experiments, the difference between maximum and minimum weight of seed in each of the skulls being about $1\frac{1}{4}$ per cent. But, considering the diversity in the shape of the skulls, and the particularly long time required to fill them, I am not surprised at this want of uniformity in density.

The average of the experiments on the three "crânes étalons" brings out the weight of 1000 cm.^{3} of the seed at 768·33 grammes, and I have adopted this as the constant relation between weight and volume. To reduce the weights to volumes, I have therefore multiplied the former by $\frac{1000}{768\cdot33}$, say 1·302, and taken the result to the nearest 5 cm.^{3}.

In order to form an idea of the relation between volume and weight of seed when packed in the measuring glasses, I filled the 1000 cm.^{3} glass ten times with the seed, shaking and tapping to about the same degree as I had done before when measuring the first 31 skulls, and then weighed the seed on the balance.

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* I make this skull 1445 cm.^{3} and obtain almost exactly 767 grs. from its weight of mustard seed. K. P.

The weights, in the order in which they were taken, were 766·10, 766·80, 764·22, 763·15, 768·95, 769·75, 766·70, 760·60, 764·25, and 764·30 grammes, the average being 765·48, and the difference between maximum and minimum weight being about 1¼ per cent. This average, it will be observed, agrees pretty closely with the average obtained from the "crânes étalons," but as it shows that the density of seed in the glass was somewhat less, say a half per cent. less, than that in the skulls, some correction should be made in the capacities which I recorded of the 31 skulls first measured. I have, as a matter of fact, reduced them one per cent., because I feel confident that, when working on these skulls, I subjected the measuring glass to a less thorough process of shaking and tapping than later on, when I came to make the ten experiments just described*.

In order to ascertain whether the state of the weather affected the weight of the seed, I put aside a quantity weighing about 756 grammes, and weighed it on six different days in January last year; two of the days were bright and dry, the others damp and cloudy. The variation in weight was less than half a gramme, and may therefore be considered negligible.

I may add that the process of determining the capacity, whether by the glass measure or the balance, was very slow; I never succeeded in taking more than three capacities in an hour.

I am fortunately able to compare the result of my method and my personal equation with those of some of the other workers at University College. Some four or five years ago G. U. Yule measured 48 of the same crania. These crania give the following results:

	Yule	*Macdonell*
21 ♂s	1531	1543
27 ♂s	1321	1329

In the averages of 21 and 27 cases our differences were 12 and 8 cm.^{3} respectively. Our average differences in reading were 20 cm.^{3} in the first and 18 cm.^{3} in the second series. I have also the measurements of 11 skulls made by A. Martin Leake. His mean value for the eleven was 1389 as against my 1400, and our average difference was 11 cm.^{3}. His average difference from G. U. Yule on these skulls was 8·6 cm.^{3}, and the latter made the mean 1385. Yule and Leake were working with mustard seed and using Flower's method. These results confirm the view that different observers using the same method may have an average difference of 10 cm.^{3}, and if they use different methods an average difference of even 20 cm.^{3}. On the other hand, with careful treatment, different measurers working with different methods will hardly differ in the averages of fairly long series by more than 10 to 15 cm.^{3}. I think we must be content with this degree of agreement at the present stage. My method of weighing after single packing is sensibly shorter than that of double packing, and it appears to give results in substantial agreement with the latter.

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* It is perhaps worth while pointing out that different results are obtained according as the vessel is filled full or only partly filled with seed, before the tapping and shaking process begins. For instance, I made the following experiments with a 1000 cm.^{3} glass measure, 64 mm. in diameter:

(1) The vessel was filled with seed, without shaking or tapping, and then tapped and shaken; when subsidence had apparently ceased, it was again filled up, and the packing went on again until it was finally filled up. The contents were found to weigh 759·60 grammes.

(2) The packing process began when the vessel was three-fourths filled; after subsidence it was filled up, then tapped again, and finally filled up with tapping. Weight of contents 775·62 grammes.

(3) The vessel was two-thirds filled without shaking or tapping and then tapped; filled to about seven-eighths full and tapped; finally filled up. Weight of contents 776·98 grammes.

(4) Similar to (3), the stages being one-third full, one-half full, and full. Weight of contents 778·52 grammes.

(6) *On the degree of Homogeneity possessed by the present Series of English Skulls.*

Considering the history of the ground where the skulls were discovered, as set forth in section (3) above, we may conclude that our material is fairly homogeneous without further inquiry, but it may be well to compare their variability in length and breadth with that of other long and probably homogeneous series.

Variability of other Series.

(Standard Deviations and Coefficients of Variation.)

Series	*L* ♂		*L* ♀		*B* ♂		*B* ♀	
	S. D.	C. of V.	S. D.	C. of V.	S. D.	C. of V.	S. D.	C. of V.
Naqada[*]	5·72	3·09	5·25	2·96	4·61	3·42	4·09	3·42
Bavarian[†]	6·09	3·37	6·20	3·57	5·85	3·89	4·89	3·39
Aino[†]	5·94	3·19	5·45	3·08	3·90	2·76	3·66	2·67
Parisians[‡]	5·94	—	—	—	5·21	—	—	—
Whitechapel English...	6·27[§]	3·31	6·22	3·45	5·28[§]	3·75	4·77	3·54
Heterogeneous Scottish	7·42	3·97	7·15	4·00	5·96	4·13	5·11	3·71

Seeing how closely our series agrees in variability for both sexes, with the homogeneous Altbayerisch crania of Professor Ranke, the conclusion that we are dealing with reasonably homogeneous material seems justified. The individual crania have also what may be described as a strong family likeness, the only widely divergent skull in the series excluded from my data was apparently that of a negro. Their mean characters agree quite closely with those of another fairly long series of English skulls, which I shall deal with in a later memoir. Their great length and dolichocephaly effectively differentiate them from any German, French or Jewish population, which might be supposed to have existed in Whitechapel*. No series of continental crania appears to have comparable characters. Judging solely by appearance and range of abnormality—in default of any published measurements—Professor Pearson suggests that the present series and in a still more marked manner the second series referred to above are closer to the Long Barrow British than to the Round Barrow British, Romano-British, Anglo-Saxon, or the "mediaeval English" which are represented in our museums. The fact that the Whitechapel series is not unique, but repeats itself in a rather intensified form in crania from another London district, seems to indicate that we are not dealing with an isolated group, but with the typical skull of the citizen of London a century or two ago. If this view be correct, there is an individuality about the London, if not the English skull which may serve to modify considerably opinions formed from the isolated, and often stringently selected "English" skulls to be found in museums and anatomical collections†. The view here suggested will, perhaps, be partially indicated by the skulls figured in our plates; it will be still more manifest in the illustrations which will accompany the account of the second or Moorfields series.

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[*] C. D. Fawcett, *Biometrika*, Vol. I. p. 424.

[†] Alice Lee, *Phil. Trans.* Vol. 196, A, p. 230.

[‡] *Biometrika*, Vol. II. p. 346.

[§] For an explanation of the difference between these results and those published in *Biometrika*, Vol. II. p. 346, see p. 191 above.

(7) *Mean Values of the Characters of the present Series, and their Comparison with those of allied and other Races.*

Tables I. and II. give the mean values of the principal characters, the probable errors of the means, and the number of skulls dealt with.

For purposes of comparison I give the data for several allied races:

(*a*) Ranke's measurements on Altbayerisch skulls from his *Beiträge zur physischen Anthropologie der Bayern,* Bd. I. The means are taken from C. D. Fawcett's Naqada Memoir.

(*b*) Würtemberg crania, from *Die anthropologischen Sammlungen Deutschlands,* XVI., *Tübingen.*

(*c*) French soldiers who died in Munich during the Franco-Prussian war—56 crania, some rather juvenile—measurements from *Die anthropologischen Sammlungen Deutschlands* X., *München.*

I owe the calculation of the means of (*b*) and (*c*) to the kindness of Dr Alice Lee.

I also add the data for one unallied race, the Naqada, which of course I owe to C. D. Fawcett.

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* As we have already indicated, Whitechapel even later than the beginning of the 19th century did not contain a mixed population of "aliens." It was a suburban district close to open fields with a fairly well-to-do resident commercial population. The riverside and rougher population was farther south, at Wapping. In 1707 fields separated Whitechapel from Wapping, and the London Docks were "Garden Grounds." The "Commercial Road" did not exist, and as late as 1806, when it did exist, fields run north and south of it in all directions.

† It is perhaps deserving of record that a German craniologist, who happened to see our second series, without a hint on our part could find nothing comparable to them but "Reihengräber Schädeln."

TABLE I.

Comparison of English Cranial Means with those of other Races.

MALE.

Character and Reference Letter	English and Allied Races							Unallied Race	
	English		Altbayerisch (Modern German)		Würtemberger (Modern German)		56 French Soldiers	Naqadas	
	No.	Mean	No.	Mean	No.	Mean	Mean	No.	Mean
(*a*) C	72	1476·94 ± 9·73	100	1503·5	91	1493·77	1473	88	1381·0
(*b*) F	138	187·35 ± ·35	—	—	—	—	—	121	183·96
(*c*) L	137	189·06 ± ·36	100	180·58	97	179·48	179·96	139	185·13
(*d*) L'	72	187·76 ± ·45	—	—	95	177·96	—	121	184·87
(*e*) B	135	140·67 ± ·31	100	150·47	96	147·88	143·41	139	134·87
(*f*) B'	132	98·02 ± ·25	72	103·70	98	97·19	96·21	140	91·06
(*g*) H	122	132·04 ± ·34	99	133·78	93	130·94	130·68	134	135·21
(*h*) OH	135	114·59 ± ·25	100	120·75	94	115	112·86	140	115·59
(*i*) LB	119	101·60 ± ·25	85	100·30	96	98·60	99·70	109	99·34
(*j*) U	131	524·25 ± ·88	99	524·35	96	517·82	518·20	118	511·02
(*k*) S	131	377·11 ± ·81	80	365·10	93	367·20	365·96	119	373·02
(*l*) Q	115	307·93 ± ·72	87	329·70	95	323·97	312·20	116	304·22
(*n*) $G'H$	75	70·17 ± ·30	56	70·80	76	71·46	68·39	85	67·59
(*o*) GB	55	90·87 ± ·45	49	95·10	94	92·46	92·46	82	95·85
(*p*) J	43	130·05 ± ·57	56	135·00	94	133·33	130·70	53	125·63
(*q*) NH	79	51·22 ± ·20	70	50·90	94	51·45	51·23	91	48·94
(*r*) NB	70	24·29 ± ·17	70	24·80	95	23·91	23·13	86	25·12
(*s*) O_1L	63	43·06 ± ·15	71*	39·90	96*	39·78	38·21*	82	43·11
(*s'*) O_1R	68	42·99 ± ·16						81	42·60
(*t*) O_2L	67	33·46 ± ·15	71*	33·72	96*	34·10	33·32*	80	32·67
(*t'*) O_2R	69	33·42 ± ·18						72	31·87
(*u*) G_1	69	48·27 ± ·22	56	44·30	75	51·68	46·57	75	55·80
(*v*) G_2	66	36·78 ± ·24	53	33·20	73	38·12	37·20	75	40·33
(*u'*) G_1'	69	44·66 ± ·21	—	—	—	—	—	—	—
(*w*) GL	73	95·93 ± ·35	—	—	—	—	—	81	94·72
(*aa*) $P\angle$	63	86°·09 ± ·33	40	89°·10	77	86°·42	86°·46	62	84°·41
(*bb*) $A\angle$	69	73°·38 ± ·28	—	—	—	—	—	73	72°·82
(*cc*) $N\angle$	69	65°·19 ± ·29	—	—	—	—	—	73	66°·60
(*dd*) $B\angle$	69	41°·43 ± ·20	—	—	—	—	—	73	40°·73
(*ee*) θ_1	59	28°·71 ± ·22	—	—	—	—	—	62	28°·29
(*ff*) θ_2	59	12°·92 ± ·29	—	—	—	—	—	62	11°·30
(α) $100B/L'$	69	75·17 ± ·24	—	—	—	—	—	101	72·70
(β) $100B/L$	131	74·34 ± ·19	100	83·20	96	82·45	79·79	130	72·99
(γ) $100H/L'$	69	70·40 ± ·22	—	—	—	—	—	98	73·20
(δ) $100H/L$	120	69·97 ± ·20	99	74·20	93	73·02	72·57	131	73·30
(ϵ) $100H/B$	116	94·31 ± ·29	99	89·10	92	88·50	—	131	100·47
(ζ) $100B/H$	116	106·26 ± ·32	—	—	—	—	109·65	131	99·76
(θ) $100G'H/GB$	53	76·52 ± ·50	48	74·50	74	78·10	74·19	76	70·63
(κ) $100NB/NH$	70	47·55 ± ·37	70	48·70	93	46·59	45·26	77	51·08
(λ) $100O_2/O_1$, L	63	77·86 ± ·32	71*	84·5	96*	85·85	87·27*	77	74·89
(λ') $100O_2/O_1$, R	68	77·69 ± ·38						76	74·87
(μ) $100G_2/G_1$	61	76·26 ± ·55	47	74·4	66	74·21	80·14*	67	71·94

* Only one eye taken, and which not stated.

TABLE II.

Comparison of English Cranial Means with those of other Races.

FEMALE.

Character and Reference Letter	English and Allied Races						Unallied Race	
	English		Altbayerisch (Modern German)		Würtemberger (Modern German)		Naqadas	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean
(*a*) C	*80*	1299·87 ± 8·51	*100*	1335·50	*18*	1336·83	*123*	1287·9
(*b*) F	*143*	180·14 ± ·36	—	—	—	—	*168*	177·41
(*c*) L	*140*	180·36 ± ·35	—	173·45	*19*	172·74	*185*	177·47
(*d*) L'	*57*	180·07 ± ·57	—	—	*19*	171·90	*159*	177·89
(*e*) B	*140*	134·68 ± ·27	*100*	143·98	*19*	142·90	*185*	131·50
(*f*) B'	*147*	93·12 ± ·23	*83*	96·30	*19*	93·90	*181*	88·23
(*g*) H	*124*	124·56 ± ·30	*96*	128·01	*19*	126·26	*169*	129·47
(*h*) OH	*143*	109·21 ± ·25	*100*	114·17	*19*	112·68	*174*	113·11
(*i*) LB	*122*	95·34 ± ·24	*90*	95·80	*19*	93·63	*141*	94·86
(*j*) U	*136*	503·84 ± ·85	*99*	501·40	*19*	500·58	*146*	493·74
(*k*) S	*130*	362·76 ± ·84	*90*	353·40	*19*	358·16	*151*	363·64
(*l*) Q	*122*	293·97 ± ·71	*97*	318·70	*18*	314·95	*151*	296·49
(*n*) $G'H$	*62*	65·93 ± ·40	*66*	66·80	*15*	65·80	*119*	65·84
(*o*) GB	*58*	84·86 ± ·41	*66*	89·70	*19*	88·50	*113*	92·51
(*p*) J	*33*	120·27 ± ·58	*67*	126·30	*18*	124·44	*63*	117·04
(*q*) NH	*67*	48·68 ± ·22	*72*	48·20	*19*	45·74	*123*	46·73
(*r*) NB	*64*	23·19 ± ·14	*72*	23·70	*19*	23·05	*119*	24·31
(*s*) O_1L	*57*	41·17 ± ·13	*79**	38·32	*19**	37·95	*118*	41·70
(*s'*) O_1R	*62*	40·95 ± ·14					*113*	41·30
(*t*) O_2L	*64*	33·59 ± ·12	*79**	33·18	*19**	32·21	*117*	32·16
(*t'*) O_2R	*64*	33·73 ± ·13					*116*	31·87
(*u*) G_1	*57*	45·13 ± ·26	*57*	42·20	*15*	50·20	*103*	53·89
(*v*) G_2	*58*	35·22 ± ·24	*55*	32·10	*15*	37·20	*103*	38·87
(*u'*) G_1'	*58*	41·53 ± ·22	—	—	—	—	—	—
(*w*) GL	*58*	90·42 ± ·40	—	—	—	—	*106*	91·02
(*aa*) $P\angle$	*52*	87°·13 ± ·27	*61*	88°·8	*14*	84°·93	*89*	84°·49
(*bb*) $A\angle$	*57*	73°·90 ± ·29	—	—	—	—	*93*	72°·62
(*cc*) $N\angle$	*57*	64°·70 ± ·23	—	—	—	—	*93*	66°·40
(*dd*) $B\angle$	*57*	41°·39 ± ·27	—	—	—	—	*93*	40°·98
(*ee*) θ_1	*50*	28°·11 ± ·24	—	—	—	—	*89*	29°·09
(*ff*) θ_2	*50*	13°·13 ± ·34	—	—	—	—	*89*	11°·82
(α) $100B/L'$	*55*	74·62 ± ·27	—	—	—	—	*146*	73·86
(β) $100B/L$	*130*	74·73 ± ·18	*100*	83·10	*19*	82·78	*169*	74·19
(γ) $100H/L'$	*55*	69·05 ± ·26	—	—	—	—	*141*	73·11
(δ) $100H/L$	*117*	69·13 ± ·18	*96*	73·90	*19*	73·17	*166*	73·22
(ϵ) $100H/B$	*115*	92·35 ± ·24	*96*	88·80	*15*	88·46	*169*	98·66
(ζ) $100B/H$	*115*	108·46 ± ·28	—	—	—	—	*163*	101·59
(θ) $100G'H/GB$	*54*	77·94 ± ·57	*58*	74·40	*15*	74·11	*106*	70·36
(κ) $100NB/NH$	*64*	47·79 ± ·33	*72*	49·20	*19*	50·33	*113*	52·31
(λ) $100O_2/O_1$, L	*57*	81·70 ± ·38	*79**	86·60	*19**	85·11	*111*	76·91
(λ') $100O_2/O_1$, R	*62*	82·46 ± ·37					*113*	77·32
(μ) $100G_2/G_1$	*51*	77·69 ± ·62	*51*	76·00	*14*	74·59	*97*	72·30

* Only one eye taken, and which not stated.

Dealing first with male skulls, I will compare our series with modern English and allied races as regards capacity, head length, head breadth and cephalic index. The measurements of L and B on the living head are reduced by 11 mm., the estimated thickness of the covering tissues, and the capacity of the modern English is deduced from A. Lee's formula, *Phil. Trans.*, Vol. 196, A, p. 252.

TABLE III.

Male Crania.

	C	L	B	B/L
Whitechapel English, 1st series ...	1477	189·1	140·7	74·3
Moorfields English, 2nd series* ...	1473	189	143·1	75·7
Modern English, 1000 upper class † ...	[1431 ?]	182·5	143	78·3
,, ,, 3000 criminals† ...	[1378 ?]	180·7	139·4	77·2
British Association†	[1495]	187·1	144·0	77·0
Altbayerisch	1503	180·6	150·5	83·2
Würtemberger	1494	179·5	147·9	82·4
French soldiers	1473	180	143·4	79·8

From these figures it appears that a marked change has been going on in the shape of English skulls during the last two or three centuries; the length has been decreasing and the breadth increasing, leading to a more brachycephalic type. This change is even more marked when we compare English with modern Germans, and it is interesting to note that C. D. Fawcett was able to show from a comparison of Naqadas with Thebans and Copts that a change in the same direction has taken place in the development of Egyptian skulls‡.

In frontal breadth, height of skull and auricular height, English agree very closely with modern Würtembergers but are inferior to the Altbayerisch. Further, in modern Germans the face breadth and zygomatic breadth are greater than in our series, while length of skull base, upper face height, nose and height of orbit are very much the same in both.

The comparatively small breadth of eye orbit in the modern races is noteworthy, and suggests that the measurement on the nasal side had been taken from the dacryon, so that comparison with our series is impossible.

The palate measurements of Altbayerisch and Würtemberger differ extremely, but it is to be observed that if we assume that the latter were measured in accordance with the Frankfurt Concordat, and we deduct 4—5 mm. from the length in order to make it comparable with ours§ (the Concordat length being measured

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[*] From unpublished measurements on a second series of skulls at University College, which will form the subject of another paper in *Biometrika* at an early date.

[†] *Biometrika*, Vol. I. pp. 181, 188, 189. These are reconstructed from Dr Lee's formulae. The absence of head height in the Cambridge students and the criminals renders the predicted skull capacity of small weight in these cases.

[‡] *Biometrika*, Vol. I. p. 433.

[§] *Biometrika*, Vol. I. p. 430.

up to the inner wall of the alveolar margin between the middle incisors, our length to a surface tangential to the inner alveolar surfaces of these incisors), we reduce the Würtemberger G_1 to 47·18. On the other hand, if we assume that the Altbayerisch were measured by Schmidt's convention, that is, in the same way as ours except that he measures from the *base* of the spina, we must add the length of the spina, say 3·6 (the difference between G_1 and G_1' in our series), thus bringing the Altbayerisch G_1 up to 47·90. The English and modern German palate length would thus be brought into fairly close agreement, but I cannot reconcile the extraordinary differences in palate breadths, and yet it is difficult to suppose that the Altbayerisch and Würtemberger differ so remarkably in this character.

Having compared our series with allied races we will now proceed to compare them with a totally different race, the Naqadas. Dealing still with the males, we see that in length, breadth, and capacity the English skull is much the larger, but in basio-bregmatic and auricular height it is inferior to the Egyptian. The greater height of the Naqada skull is very marked, and this has the effect of bringing the English and Naqada sagittal and cross circumferences quite near each other. There is also a very marked difference between the two races in the *face*; the Naqada face is much broader, and the nose shorter and broader. Allowing for the method of measuring the breadth of the Naqada orbit*, we find that the Naqada *eye* was considerably smaller, both in height and breadth, and rounder, the orbital index calculated on the amended breadth of orbit being about 78·8 as against the English average 77·8. The great difference in *palate* length is partly due to the adoption of different systems of measurement; deducting 4·87 mm. from the Naqada mean†, in order to make it comparable with the English mean, we still find the Naqada palate considerably the longer, being 50·93 mm. as compared with the English 48·27 : it is also very much the wider.

While differing in all other respects, there is a remarkable agreement between the English and Naqada skulls as regards the angles θ_1 and θ_2, and also the angles of the triangle formed by joining the nasion, basion, and alveolar point: that is, although the sides of this triangle are longer in the English skulls than in the Naqada, the included angles are nearly the same, or the triangles are nearly "similar" in the two races. I will return to this point further on.

Turning now to female skulls, I am not aware of any measurements of modern French female heads available for comparison with our series; the following table is therefore less complete than No. III.

We note as in the case of the males that the skull appears to be growing shorter. The breadth does not here appear to have sensibly increased, but greater capacity has been obtained by increased auricular height.

A comparison with modern Germans leads to results very similar to those which we found when comparing the males of the two races. The modern German skull is shorter and broader than the English; in frontal breadth, however, the

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* *Biometrika*, Vol. I. p. 431.

† *Biometrika*, Vol. I. p. 430.

English agree very closely with the Würtembergers but in basio-bregmatic and auricular height are inferior to both German series, especially to the Altbayerisch, also in face breadth and zygomatic breadth they are markedly inferior. In length of skull base, upper face height, nose and height of orbit, our series and the Altbayerisch are very nearly alike; in these characters the Würtembergers are smaller than the other two, especially in height of nose.

TABLE IV.

Female Crania.

	C	L	B	B/L
Whitechapel English, 1st series	1300	180·4	134·7	74·7
Moorfields „ 2nd series* ...	1330	183·7	137·6	74·9
Modern English, London Students† ...	[1356]	178·7	135·8	75·8
„ „ British Association ...	[1324]	174·6	137·3	78·6
Altbayerisch...	1335	173·4	144	83·1
Würtemberger	1336	172·7	142·9	82·8

The eye measurements again suggest that the breadth was measured from the dacryon, and in the case of the palate we are again met by a very marked difference between Altbayerisch and Würtemberger. If we assume that the former were measured by Schmidt's convention, we shall have to add the length of the *spina*, which in our series is 3·6 (the difference between G_1 and G_1'), to the length given in the table; this would make the Altbayerisch $G_1 = 45·80$. In the case of the Würtembergers, assuming that they were measured in accordance with the Frankfurt Concordat, we must make a deduction from the length to make it comparable with that of our series, say a deduction of 4 mm.‡, thus reducing G_1 to 46·20. In this way we should bring English and modern German palate lengths into close agreement, but in the absence of information as to the German methods of measurement the agreement is purely hypothetical, as in the case of the male crania.

The discordance in palate breadth between English, Altbayerisch, and Würtemberger is again very noticeable.

We will now compare our series with the Naqadas, with similar results to those which we found when comparing the male crania. The English skull is the larger in all the *lengths* except basio-bregmatic and auricular height; in both of these characters the Naqada skull is considerably loftier. The Naqada *face* was much broader, and the nose shorter and broader. The Naqada *orbit* also, when allowance is made for the method of measurement, is found to be smaller than the English, but, unlike the male, *less* round, and the palate was much longer and broader.

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* These are the crania referred to in the Note on p. 210, *supra*.

† A small series of Bedford College Students, to which probably not much weight must be attached. See A. Lee, *loc. cit.* p. 258. A modification has been made in the calculated capacity as it is probable that the auricular height is about 4 mm. too large.

‡ *Biometrika*, Vol. I. p. 430.

We will conclude our comparisons by referring to the triangle whose apices are the basion, nasion, and alveolar point; the sides of this triangle are very nearly equal in both races and the contained angles are therefore nearly equal; and further, we have this remarkable fact, that these angles closely approximate to the angles of the corresponding triangle for male crania, both English and Naqada. Whether or not we have a specific character in this triangle further research alone will show. It is greatly to be desired that measurements of it should be made on the long series of skulls possessed by many German museums.

As the mandibles are unsexed, they are given in a separate Table.

TABLE V.

Comparison of Means of English Mandibles with those of the Naqada race.

Character and Reference Letter	English		Naqada					
	Male and Female		Male		Female		Male and Female	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean
(x) W_1 ...	*108*	113·21 ± ·41	*41*	110·49 ± ·87	*52*	106·37 ± ·67	*93*	108·19
(y) W_2 ...	*151*	95·40 ± ·46	*51*	93·58 ± ·67	*59*	87·62 ± ·55	*110*	90·38
(z) h_1 ...	*133*	30·76 ± ·21	*60*	32·91 ± ·28	*75*	31·61 ± ·21	*135*	32·19
(z') f ...	*170*	43·67 ± ·14	*49*	44·44 ± ·25	*60*	43·12 ± ·20	*109*	43·71

The points to be noticed are: (1) the English skulls have greater condylar and angle widths, and (2) a smaller "maximum height" of mandible than the Naqadas; but (3) the distance between the *foramina mentalia* is nearly the same in both races.

Having dealt with the means, we turn to the *indices* of the English skulls, and giving them their classes according to the Frankfurt Concordat we can now compare the two sexes.

Here we find no marked difference between the two sexes except in the shape of the eye orbit, which is much rounder, and in the palate, which is less leptostaphyline in the female than in the male. In the Altbayerisch skulls also, there are no marked sexual differences except in eye orbit and palate, and in these characters the sexes differ in the same way as our English series. The Würtemberg skulls, however, differ both from English and Altbayerisch in this respect, that the chief differences between the sexes in this group are in upper face index and nasal index: the males have a much narrower face and much longer nose than the females.

The great general likeness between the sexes in English and modern Germans is in marked contrast to the sexual diversity that prevailed amongst the Naqadas.

TABLE VI.

Specification of English Crania.

Character	Class		Remarks
	♂	♀	
(β) $100B/L$	Dolichocephaly	Dolichocephaly	Both sexes alike
(γ) $100H/L$	Chamaecephaly	Chamaecephaly	Both sexes are on the borders of orthocephaly, the male rather more closely than the female
(*aa*) Profile Angle ...	Mesognathy	Mesognathy	The female tends rather more than the male to hyperorthognathy
(θ) Upper Face Index ...	Narrow faced	Narrow faced	The female is the narrower
Zygomatic „ „ *„ ...	Leptoprosopy	Leptoprosopy	♂ index 53·77; ♀ index, 54·82†
(λ) Orbital Index ‡ ...	Chamaeconchy	Mesoconchy	Left eye index practically the same as the right eye index in both sexes
(κ) Nasal Index	Mesorrhiny	Mesorrhiny	Both sexes alike, and not far from leptorrhiny
(μ) Palate Index ‡ ...	Leptostaphyline	Leptostaphyline	The female tends more to mesostaphyline
Alveolar Index* ...	94·42	94·84	Sexes practically alike §

General Points.

(*a*) The average male skull is significantly larger than the average female skull, except in the case of the breadth of the eye orbit, in regard to which the sexes are practically alike.

(*b*) In both sexes the breadth of the skull is significantly greater than the height, the excess being greatest in females.

(*c*) The left orbit is practically the same as the right orbit for both length and breadth in both sexes, and in the case of the breadth both sexes are practically alike. C. D. Fawcett found the left orbit to be larger than the right in the Naqadas, and has collected cases of asymmetry in other parts of the skeleton‖.

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[*] These indices are simply the ratios of the means of the characters. The alveolar index $100\,GL/LB$ is not considered in the *Frankfurter Verständigung*. The zygomatic upper face index is $100\,G'H/J$.

[†] For Altbayerisch skulls this index is, for ♂ 52·4; for ♀ 52·8; for Würtemberger, ♂ 53·6, ♀ 52·9; for the small series of French soldiers 52·3.

[‡] The methods of measurement which I have adopted have to be borne in mind; if I had measured by the Frankfurt Concordat both sexes would have shown chamaeconchy, but would have remained leptostaphyline.

[§] For Naqadas this index is for ♂ 95·35; for ♀ 95·95.

[‖] *Biometrika*, Vol. I. p. 436.

(*d*) My measurements confirm C. D. Fawcett's conclusion[*] that there is little advantage in measuring all three lengths, F, L, and L'; in the female skulls the difference between them is hardly appreciable, and the indices involving L and L' are almost identical. In the male skulls, the difference between F and L' is within the limits of random sampling; the difference between indices involving L and L', however, is beyond these limits.

(8) *Photographic Study of the English Skull*[†].

The present photographic study of the English skull consists of two parts. The first deals with the normal skull, and the second with special skulls showing points of anatomical or pathological interest.

(*a*) *Normal Crania.*

In selecting normal crania, for reproduction, we have been guided by the desire to show not only "modal" individuals, but individuals at some distance from the mode on either side. Thus W. 45 ♂ is a typical English skull. We have for example:

Character	C	L	B	H	OH	U	S	Q	NH	NB	GL	B/L	H/L	NB/NH	O_2/O_1
Mean Male Skull	1477	189	141	132	115	524	377	308	51	24	96	74	70	48	78
W. 45	1495	190	141	136	114	521	382	307	53	24	96	74	72	45	75

Accordingly this skull is represented in four aspects on Plates I—IV[‡]. A more dolichocephalic type ($B/L = 70$), W. 76 ♂, is represented in Plates V—VII. This is by no means an extreme form: it does not present the lowness (see Plate V) of some of the very dolichocephalic English crania. It contrasts favourably with W. 88 ♂ which also has $B/L = 70$, but $H/L = 58$ as compared with the $H/L = 69$ of W. 76. Turning to more brachycephalic skulls of the same series we have pictured W. 163 ♂, a somewhat damaged but very interesting skull in Plates X—XIII, the *N. facialis* was of little use owing to the defect in the vault. Here B/L reaches 80·5. It is interesting to note that this result is obtained by a great increase in breadth, in this case 153 mm., beyond that of the typical skull W. 76; the length remains the same. The like point is illustrated in Plates XIV and XV, where the racially brachycephalic skull W. 147 ♂ is given in *N. facialis* and *N. occipitalis*. The length is in this case 191 and breadth 148 with cephalic index 77·5. So that again the increased rotundity is not gained by loss of length. Lastly in Plates VIII and XI we give examples of two skulls W. 69 ♂ and W. 7101 ♂ of nearly average length, but with total heights above the average. W. 69 is racially dolichocephalic and W. 7101 racially brachycephalic, the indices being 71 and 79 respectively. The total lengths differ by only 2 mm. and the total heights by only 2 mm., but the difference in breadth amounts to upwards of 16 mm. This is another illustration of the great influence of absolute breadth in determining cephalic index within the race. Both W. 7101 and W. 69 are "fine" crania—if we look at them from the aspects which show the breadth and height in the first and the length and height in the second, i.e. the aspects shown in our photographs.

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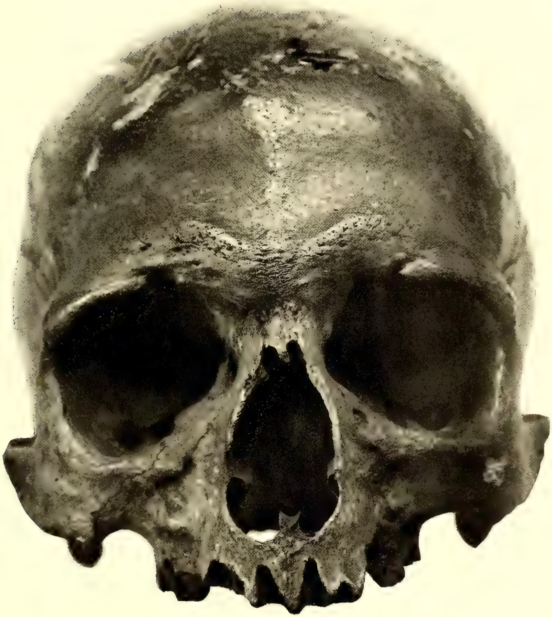
[*] *Biometrika*, Vol. I. p. 436.

[†] The photographs from which these illustrations were reproduced were taken by Professor Karl Pearson; it was a long and laborious piece of work, and my heartiest thanks are due to him for this addition to my paper. The cost of reproduction was defrayed from a grant placed at his disposal last year through the munificence of the Drapers' Company. Professor Pearson is further responsible for the drawing up of this section of my memoir. But its possibility is due entirely to the kindness of Professor Thane, who gave up a large portion of his valuable time to a close study of the special points of anatomical interest in the individual crania.

[‡] The scales are here for *N. lateralis*, *N. basalis*, and *N. verticalis* two-thirds natural size and for *N. facialis* seven-eighths, but it was found impossible to maintain this accurately throughout the series as the focus must be an average focus, and the control of the engraver could not be complete. After some experimenting with various methods the idea of uniformity of scale was discarded in favour of getting the photograph with the clearest detail. In the case of the "special" skulls, the endeavour was made to get the special detail to be illustrated, at the expense very often of the remainder of the object and entirely of scale. In the case of the "normal" skulls, a uniform system of orientation has been attempted, based on the German horizontal plane, the auricular vertical plane, and the median plane of the skull. If, however, the skull supports are not to interfere with the effectiveness of the photograph, this orientation will not be absolutely exact. On the whole we believe that the real and invaluable advantage of photographic reproduction is to show the indescribable in type and abnormality; it cannot be properly used to replace an elaborate system of individual measurements.

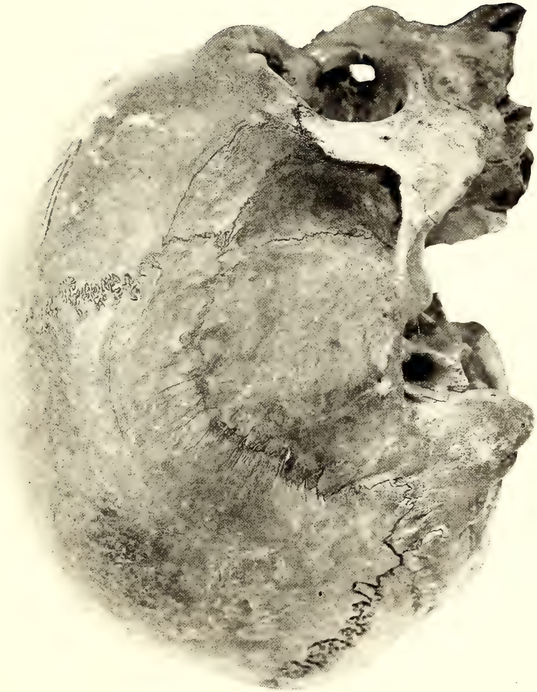
Turning to the female crania, Plates XXVII—XXXI give in five positions W. 149 ♀, a fairly typical English female skull. It is slightly larger than the average in length and breadth, but somewhat less in height, but the cephalic index 74·6 is practically identical with the 74·7 of the whole series. Plates XXV, XXVI give two views of W. 7044 ♀, which has precisely the same cephalic index 74·6, but while slightly less than the average in length and breadth has rather more than the average height. Thus the modal female skull of the series lies between W. 149 and W. 7044. To complete the general conception of the female skull we have selected a hyperdolichocephalic individual W. 10 ♀ with index 69 for reproduction in Plates XVI—XIX. This is by no means a very extreme type; the slight plagiocephaly and the infantile type of forehead render the skull otherwise of some interest. In W. 18 ♀, Plates XX—XXIV, we have a complete representation of a racially brachycephalic individual, cephalic index 79. This skull is again not extreme and while almost the average in both total and auricular heights, is less than the average in length and more in breadth.

We have endeavoured to give in these "normal" crania, some conception of the skulls of this English series. We have reproduced for both sexes modal individuals and then individuals deviating from the mode in the directions of greater dolichocephaly and of greater brachycephaly. It is open to the craniologist with a monomania for "types" to differentiate our series into two, three or more types on the basis of our illustrations. We have purposely offered the material upon which it can be done, because we believe that not only the tables of measurements, but familiarity with the material itself, will prove a complete and continuous linking



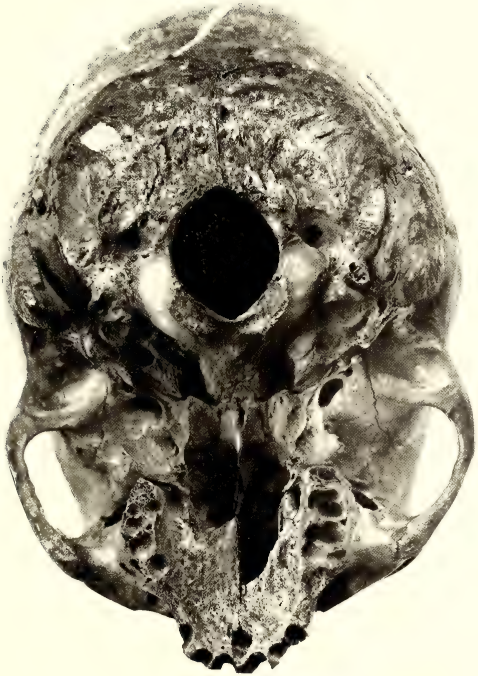
Normal Male Skull. W. 45.

N. facialis



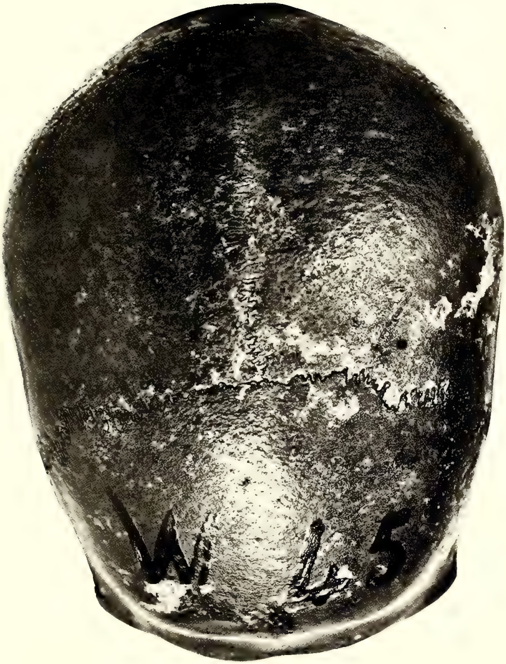
Normal Male Skull. W. 45.

N. lateralis.



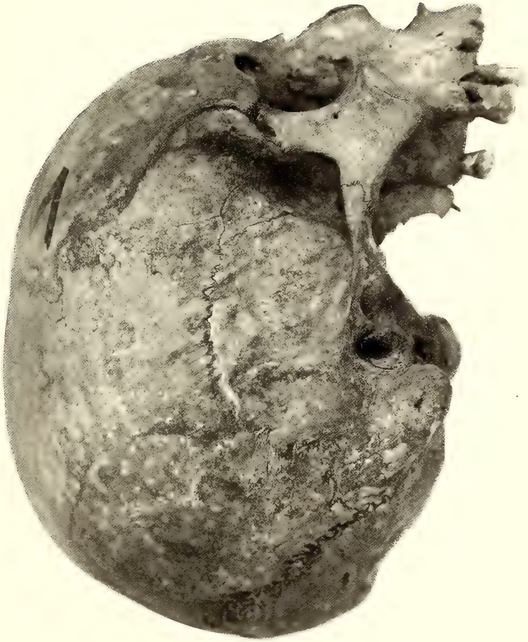
Normal Male Skull. W. 45.

N. basalis.



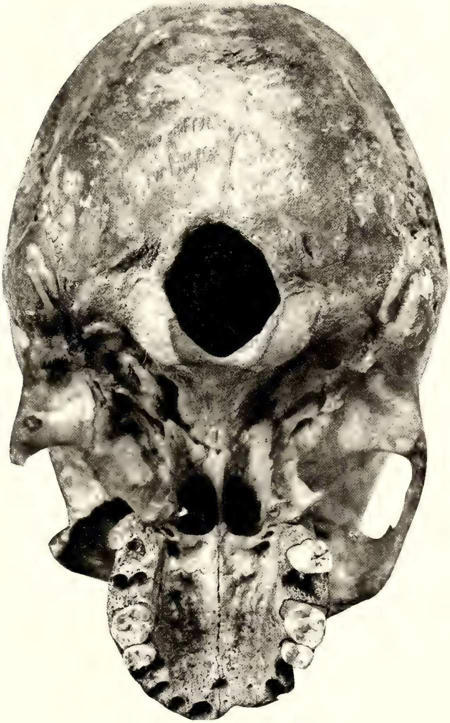
Normal Male Skull. W. 45.

N. verticalis.



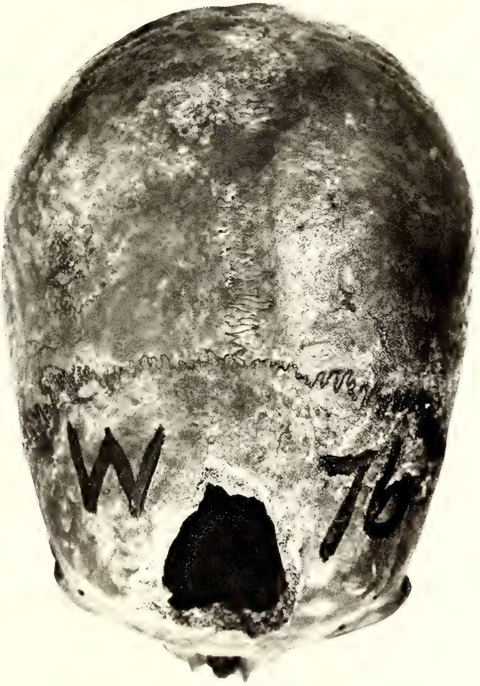
Normal Male Skull. W. 76.

N. lateralis.



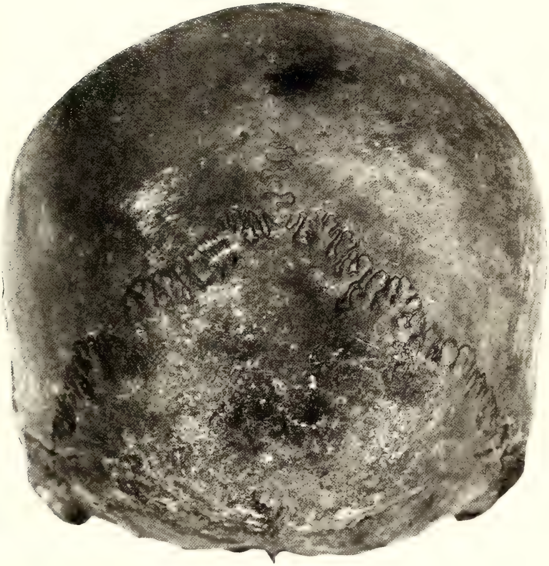
Normal Male Skull. W. 76.

N. basalis.



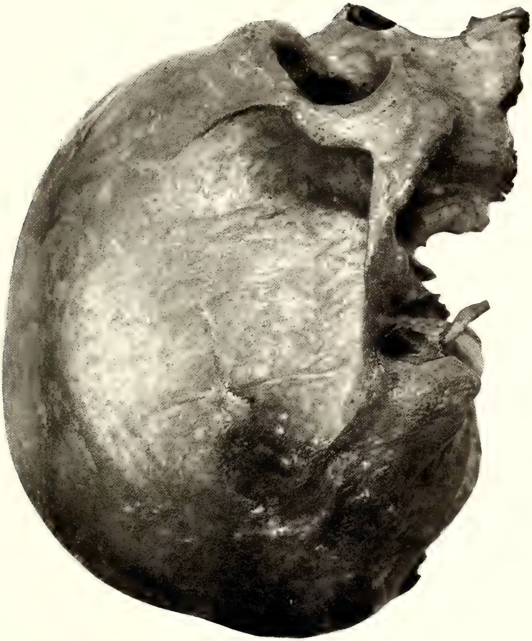
Normal Male Skull. W. 76.

N. verticalis.



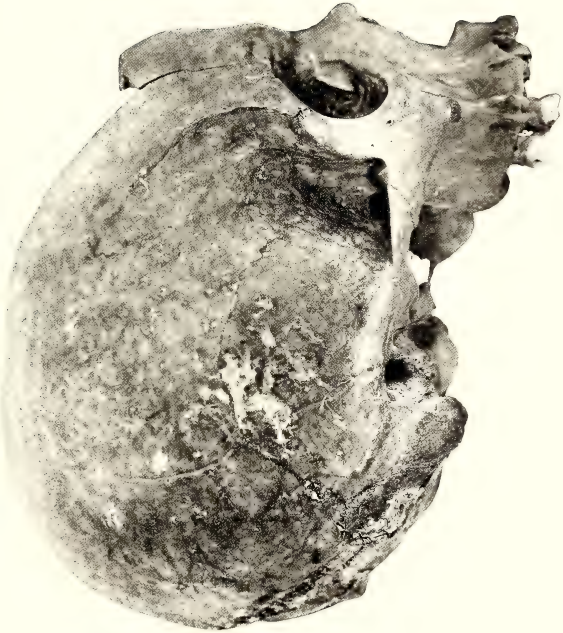
Normal Male Skull. W. 7101.

N. occipitalis.



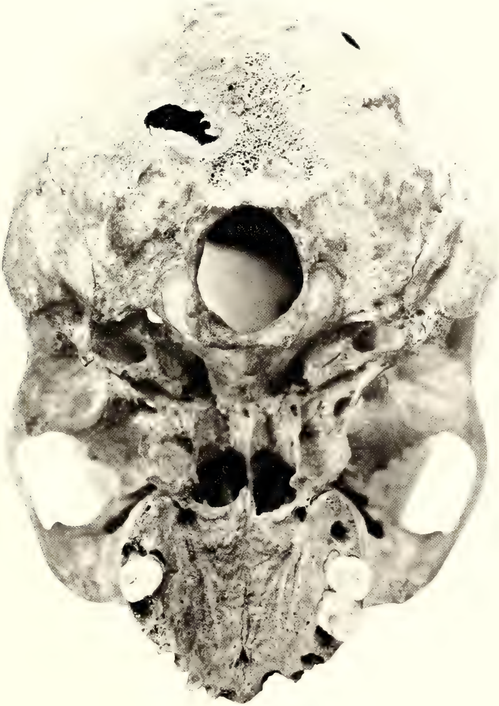
Normal Male Skull. W. 69.

N. lateralis.



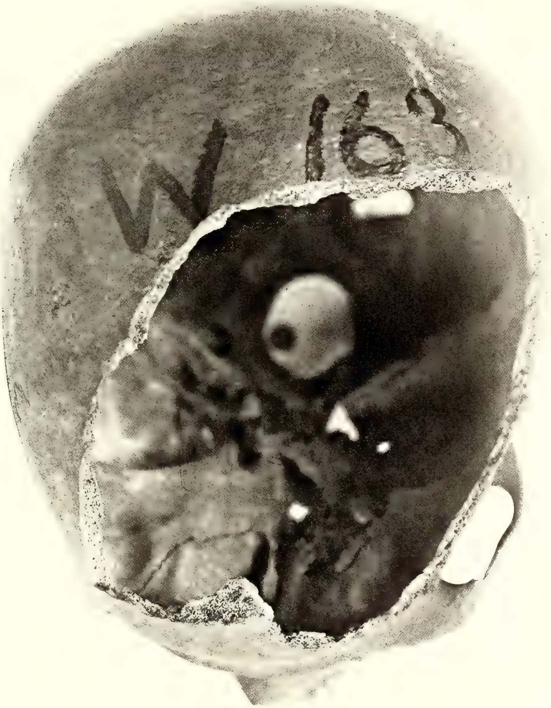
Normal Male Skull. W. 163.

N. lateralis.



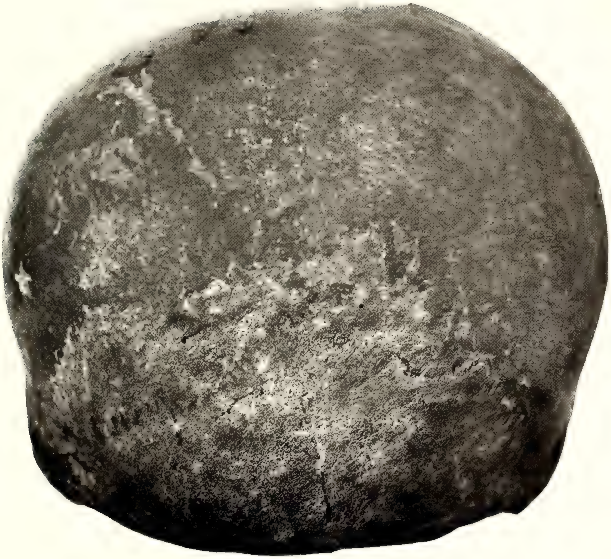
Normal Male Skull. W. 163.

N. basalis.



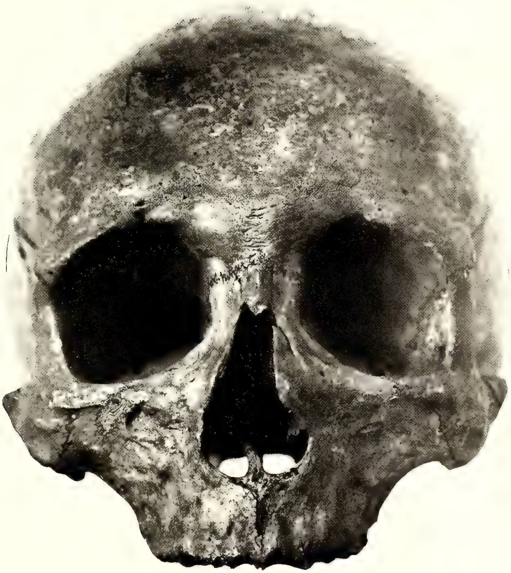
Normal Male Skull. W. 163.

N. verticalis.



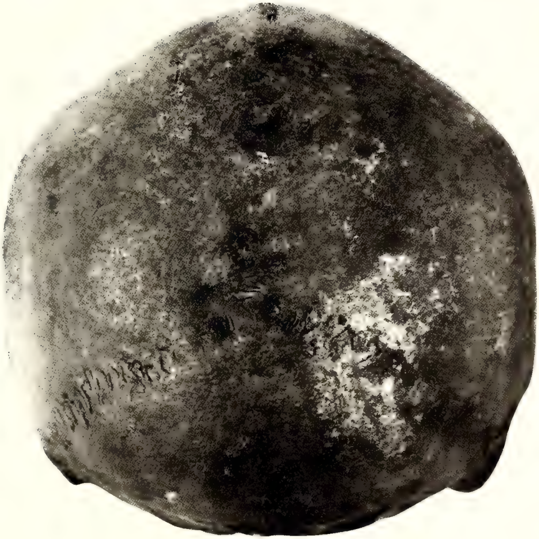
Normal Male Skull. W. 163.

N. occipitalis.



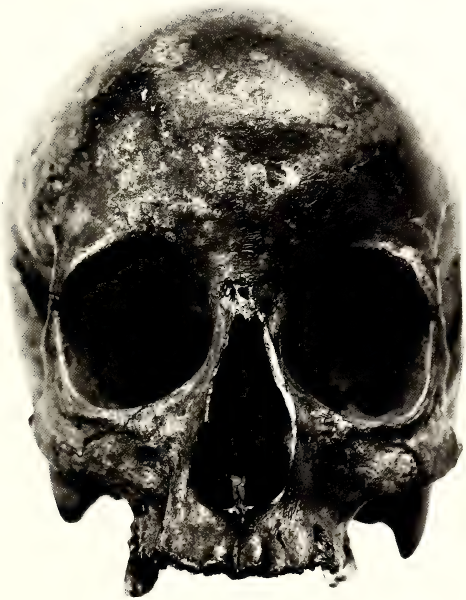
Normal Male Skull. W. 147.

N. facialis.



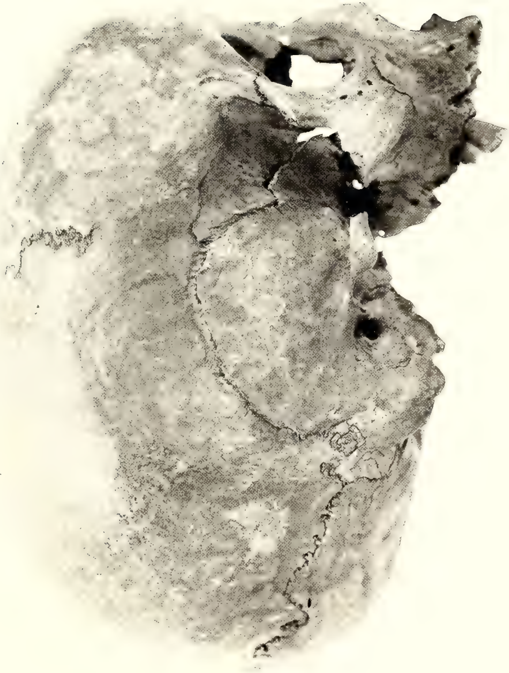
Normal Male Skull. W. 147.

N. occipitalis.



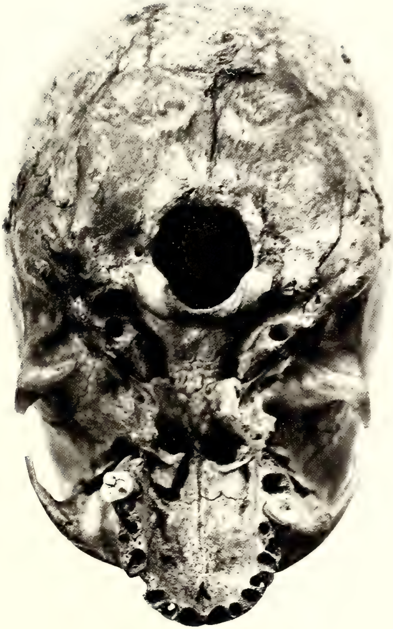
Normal Female Skull. W. 10.

N. facialis.



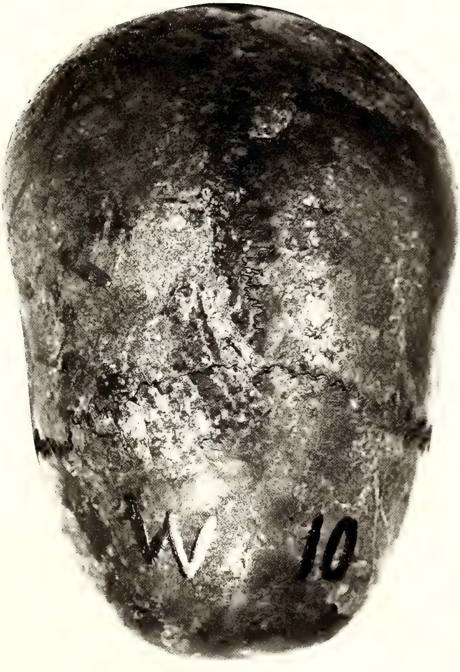
Normal Female Skull. W. 10.

N. lateralis. Young adult. Infantile type of Forehead.



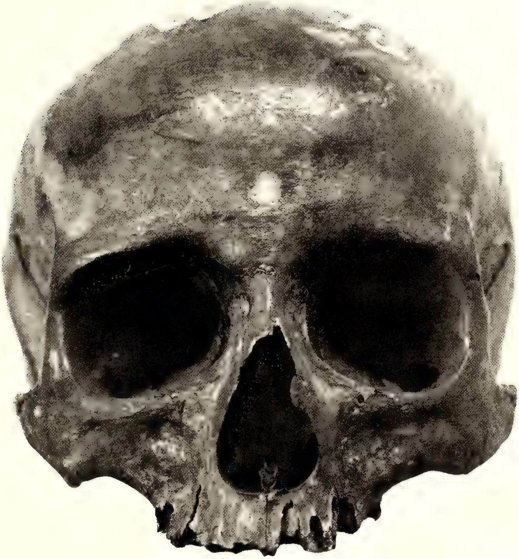
Normal Female Skull. W. 10.

N. basalis.



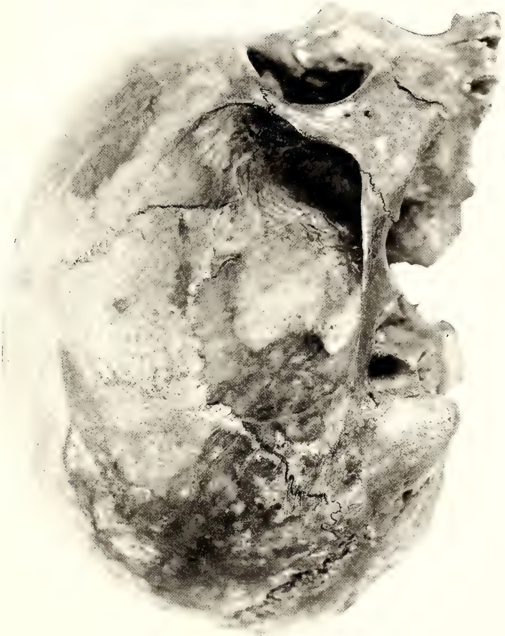
Normal Female Skull. W. 10.

N. verticalis.



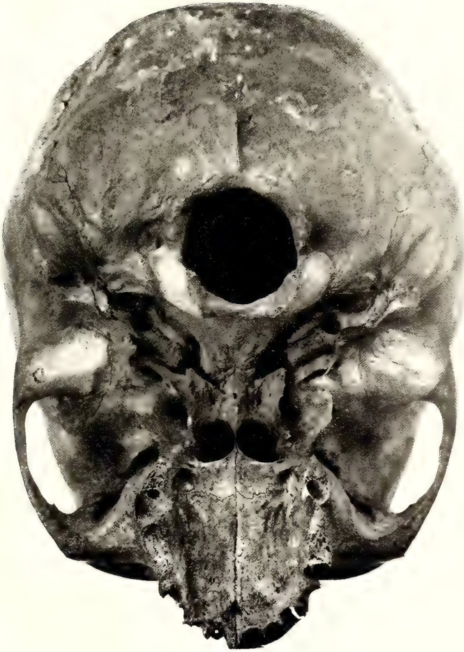
Normal Female Skull. W. 18.

N. facialis.



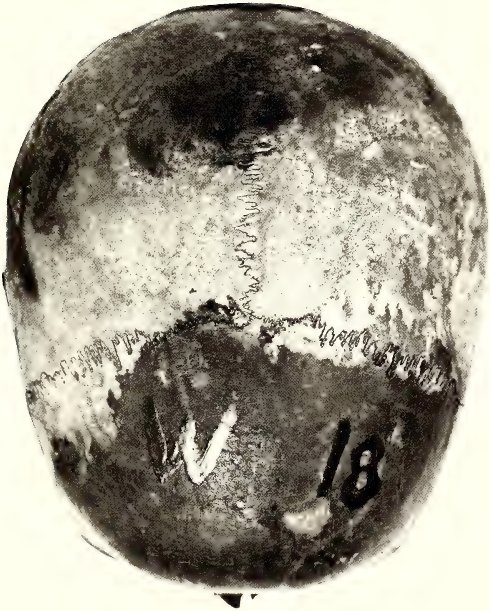
Normal Female Skull. W. 18.

N. lateralis.



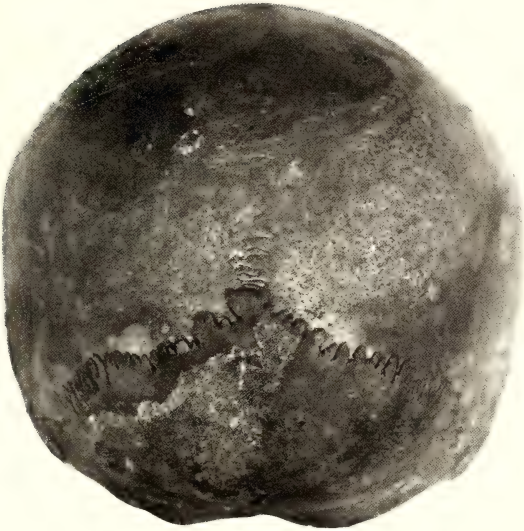
Normal Female Skull. W. 18.

N. basalis.



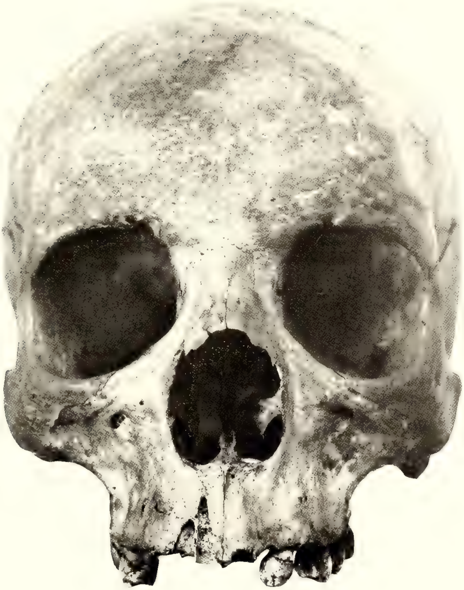
Normal Female Skull. W. 18.

N. verticalis.



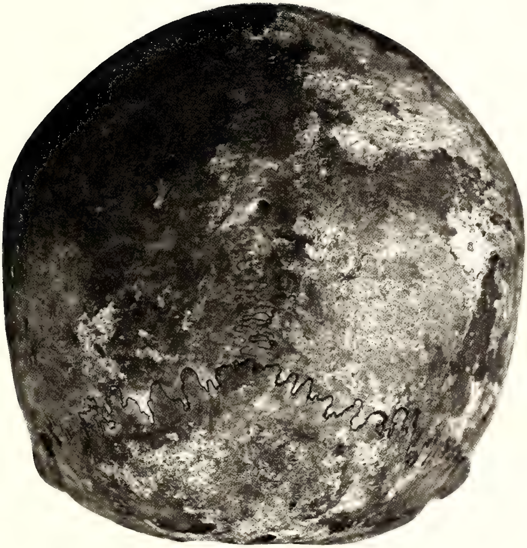
Normal Female Skull. W. 18.

N. occipitalis.



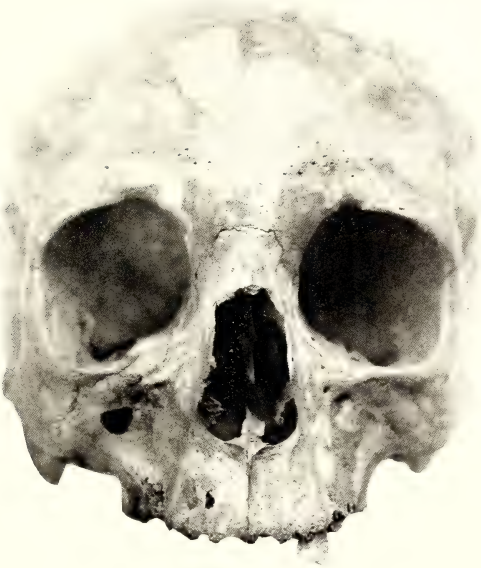
Normal Female Skull. W. 7044.

N. facialis.



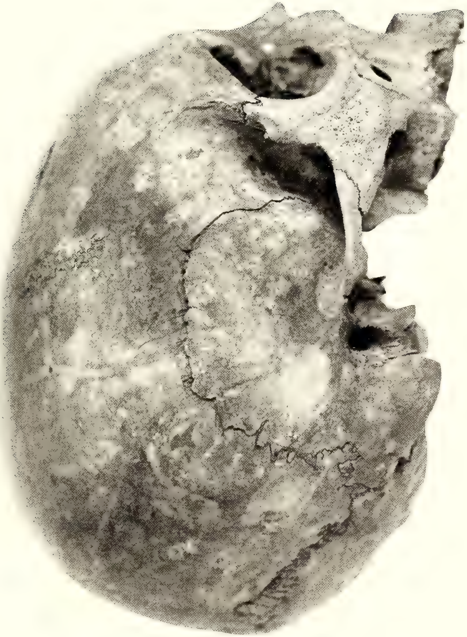
Normal Female Skull. W. 7044.

N. occipitalis.



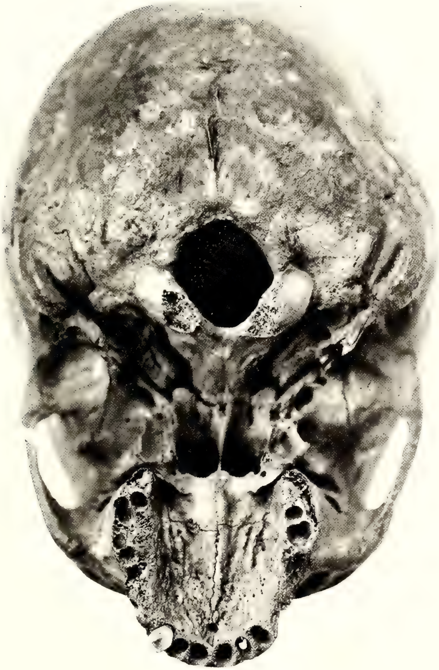
Normal Female Skull. W. 149.

N. facialis



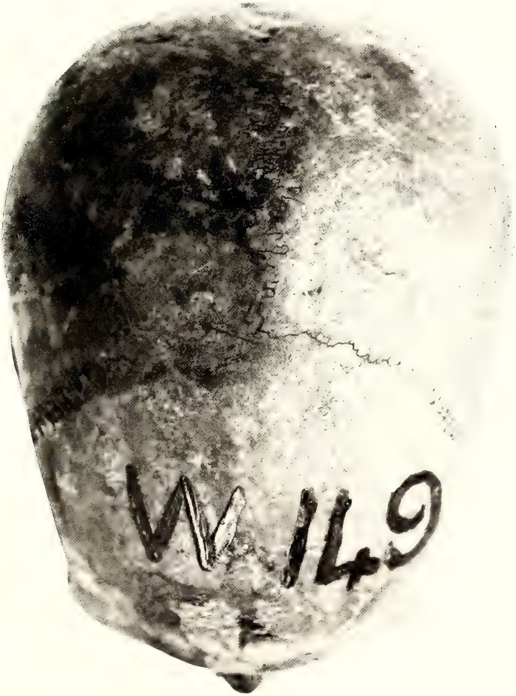
Normal Female Skull. W. 149.

N. lateralis.



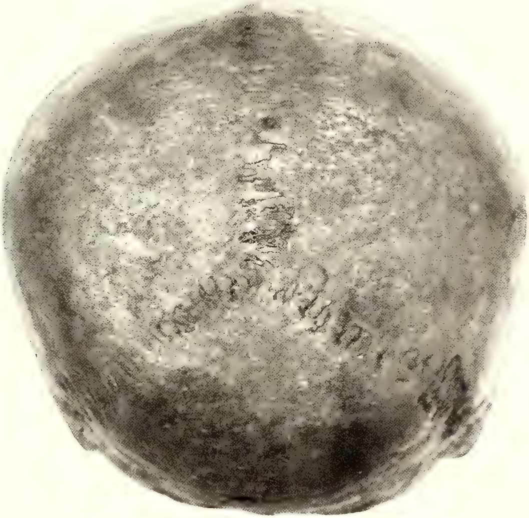
Normal Female Skull. W. 149.

N. basalis.



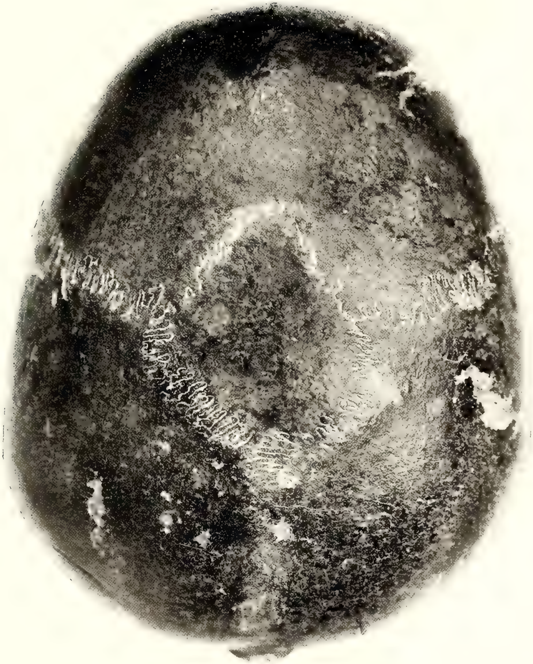
Normal Female Skull. W. 149.

N. verticalis.



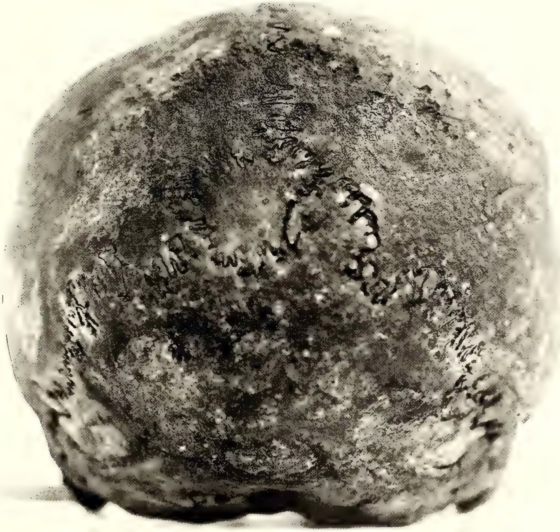
Normal Female Skull. W. 149.

N. occipitalis.



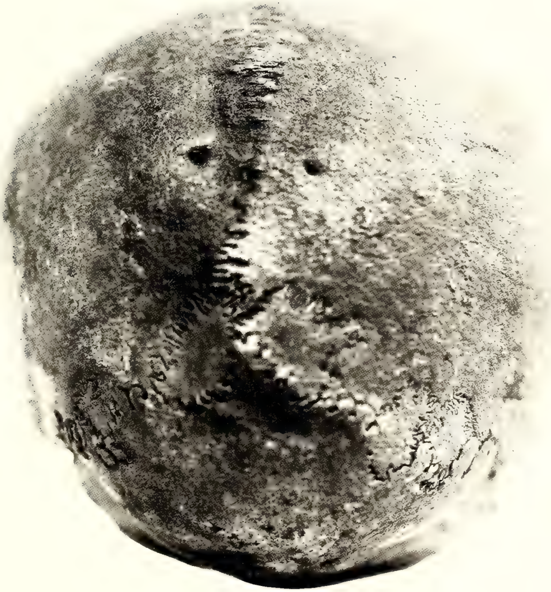
Special Skull. W. 7042.

Ossicle of Bregma



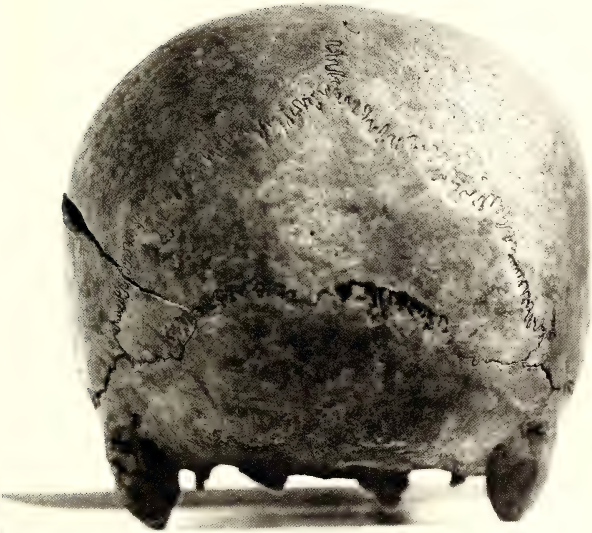
Special Skull. W. 223.

Ossicle of Lambda.



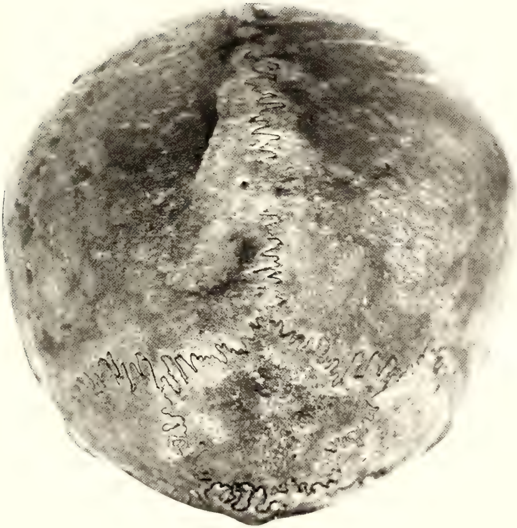
Special Skull. W. 226.

Double Ossicle of Lambda.



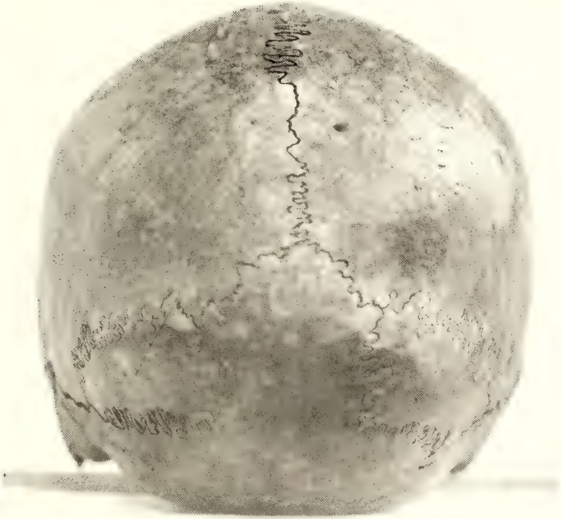
Special Skull. W. 217.

Simple Interparietal.



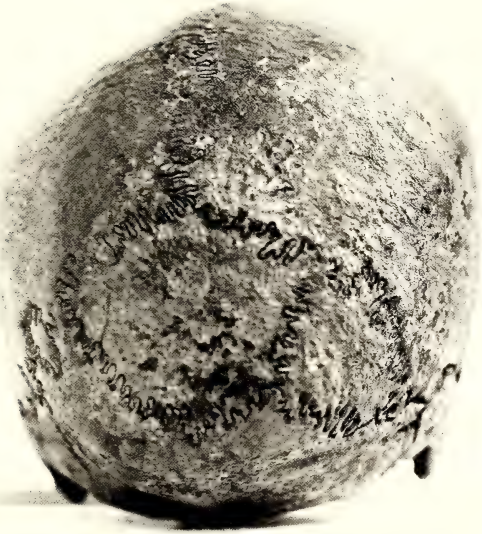
Special Skull. W. 7096.

Tripartite Interparietal. Os pentagonale and ossa triangularia all separate.



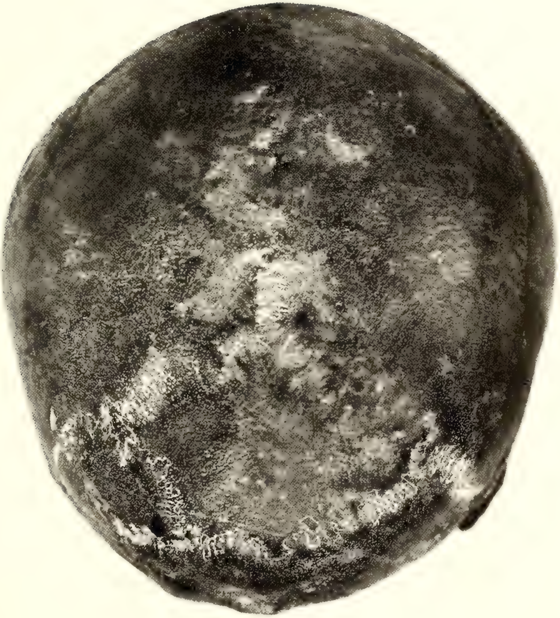
Special Skull. W. 218.

Tripartite Interparietal. Ossa triangularia only separate.



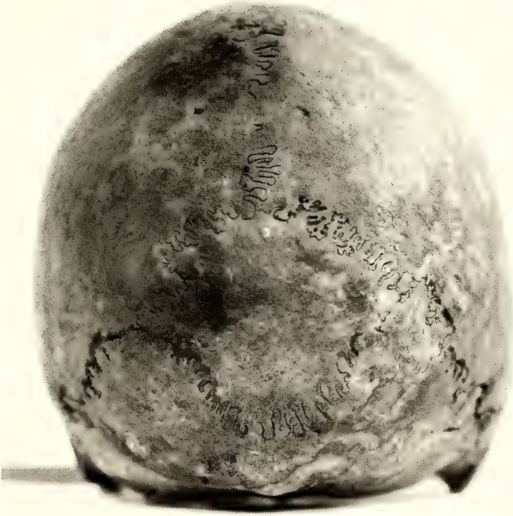
Special Skull. W. 219.

Tripartite Interparietal. Os pentagonale and right Os triangulare separate.



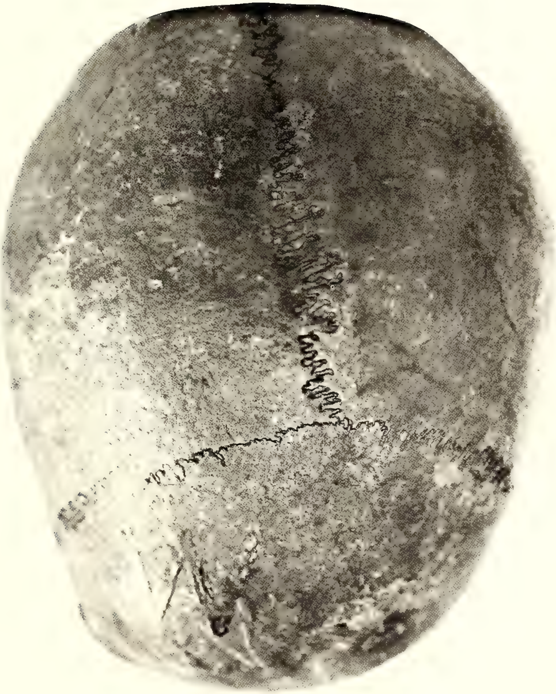
Special Skull. W. 7052.

Tripartite Interparietal Os pentagonale and left os triangulare separate.



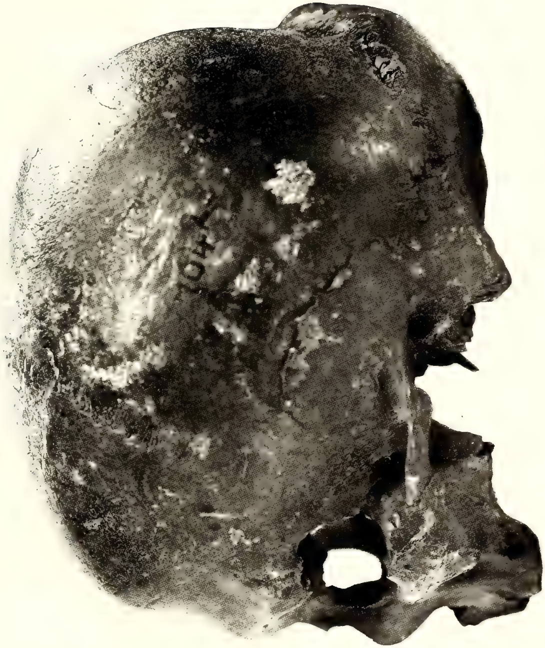
Special Skull. W. 221.

Tripartite Interparietal. Os pentagonale only separate.



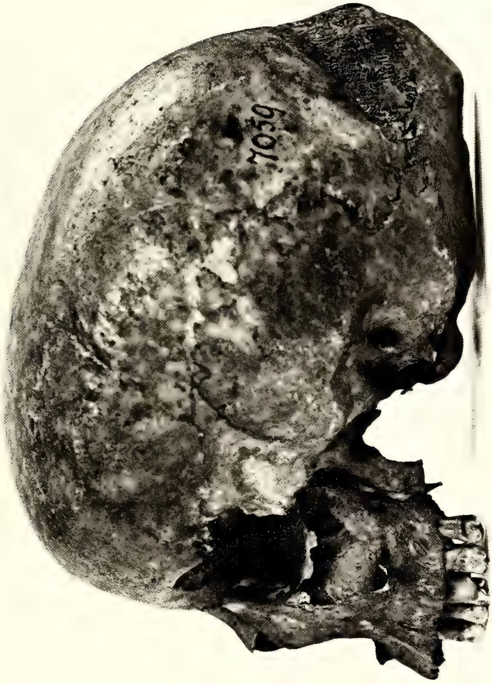
Special Skull. W. 231.

Plagiocephaly.



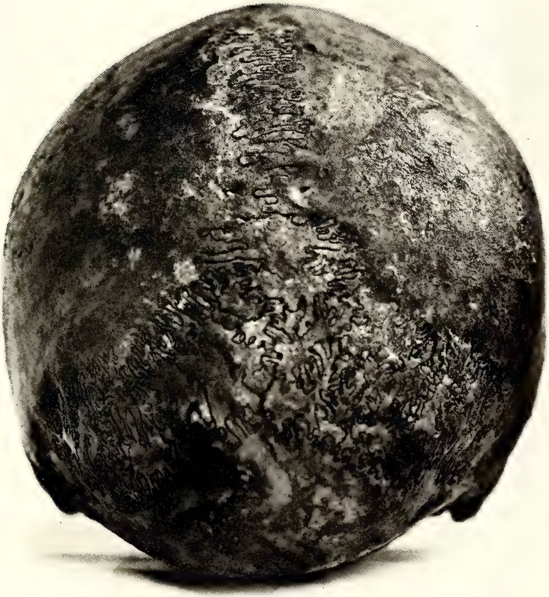
Special Skull. W. 7042.

Bathrocephaly.



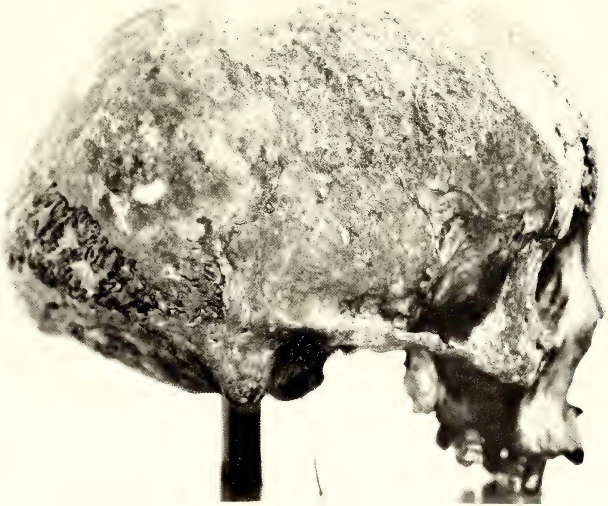
Special Skull. W. 7059.

Bathrocephaly with Ossicles of Lambdoid Suture. Left Profile.



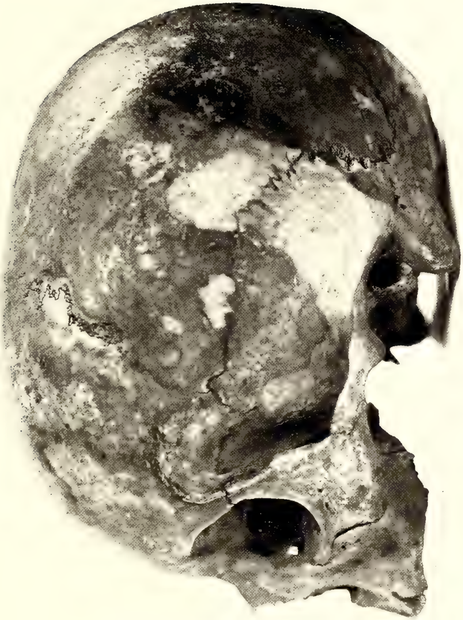
Special Skull. W. 7042.

Bathrocephaly with Ossicles of Lambdoid Suture.



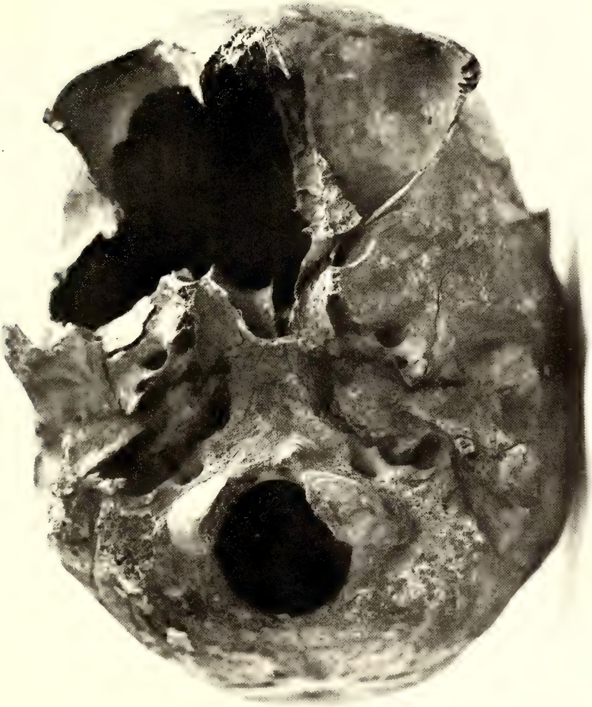
Special Skull. W. 7059.

Bathrocephaly with Ossicles of Lambdoid Suture. Right Profile.



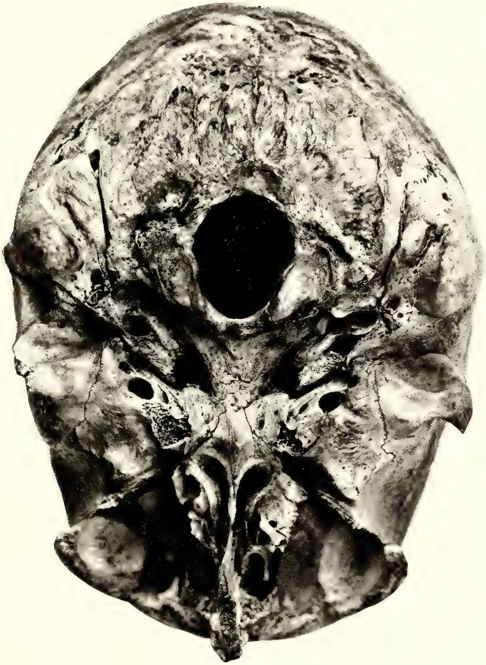
Special Skull. W. 215.

Frontal Process of Temporal.



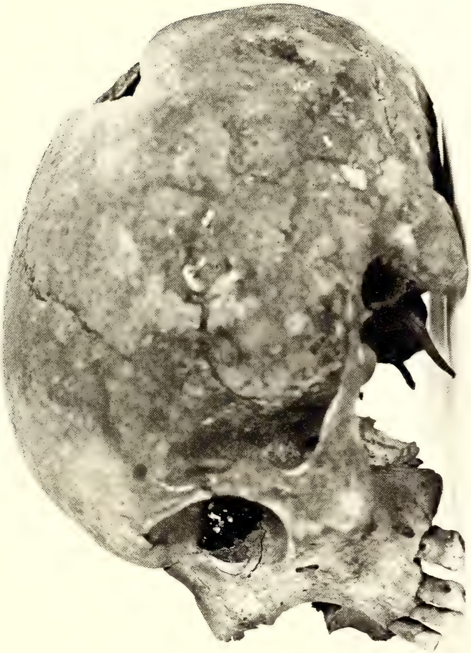
Special Skull. W. 214.

Unilateral Precondylar Eminence.



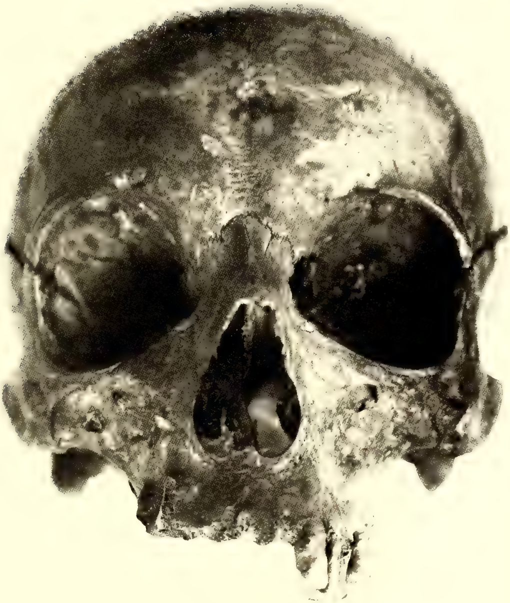
Special Skull. W. 213.

Bilateral precondylar Eminences.



Special Skull. W. 229.

Hamulus lacrimalis



Special Skull. W. 229.

Hamulus lacrimalis.

up for all characters between the individuals we have selected for representation, and that it is nowhere possible to draw a line and say, here one "type" begins and there another ends. Take the material, however, as a whole whether in our tables of means, or in our tables of measurements or in the plates, and compare it with other series, German, or French, or Scandinavian and we see at once that it has a very marked individuality of its own; that the English, or at any rate the London, skull of post-mediaeval times is a type *sui generis*. Whether this be the result of *Blutvermischung*, of selection or of environmental influence or of an absolute difference of ancestry it might be hard to determine. But the fact remains perfectly certain, the English modal skull is markedly differentiated from those at any rate of central and southern Europe.

(*b*) *Special Crania.*

Out of the 292 skulls in this collection, 164 were noted as having some, it may be slight, anatomical peculiarities. As a rule such peculiarities were likely to occur in groups. Thus 280 peculiarities were recorded, or an average of ·96 to each skull in the series, and 1·71 to each skull specially recorded for abnormality. Of these abnormalities 151 were recorded in skulls supposed to be female and 129 in skulls supposed to be male; the total number of skulls adjudged female was 151 and adjudged male 141. In other words the abnormalities were on an average one to each female and ·91 to each male skull. It will thus be seen that what greater tendency there is to abnormal variation lies in the female rather than in the male skull. Here as in every case where really scientific methods are applied to the problem there seems no reason for asserting that men show a more marked variational tendency than women.

If we turn to the individual anomalies recorded, it may be noted that some of them are very slight, but still the general frequency of anomalous characters seems higher than in most long series of skulls. At first it appeared that possibly the fact noticed on p. 196 (iv) might explain this high frequency, but a second series of London skulls shows the same high, if not a higher, proportion. We are therefore forced to the conclusion that the English skull is probably remarkable for anomalous variations; in this respect no series we have yet examined appears its equal, except possibly the Esquimaux series at Oxford. Our photographs will show how wide a range of anomalous variation can be represented from this one group.

We shall now proceed to consider some of the individual cases, classifying them under:

(i) *Peculiarities of Form.*

A very frequent anomalous form consists in a *post coronal constriction*. We have spoken of this merely as a *post coronal depression*, if it is localised about the bregma. Post coronal constriction occurred in 19 crania, of which 15 were female, and 4 male, one of the latter being of very doubtful sex. Post coronal depression in 27 skulls of which 15 were female and 12 male. Of course depression passes insensibly into constriction, but the constriction is so markedly more a female than a male character, that for some time one was inclined to consider it might be due to some feminine habit of wearing a tight band round the head.

Depression of the obelion occurs in 19 skulls, of which 12 were female and 7 male; flattening of the obelion was noted in one male and a groove of the obelion in one male and one female skull. A coronal groove was also recorded in one male skull. There were isolated cases of parietal flattening and depression of the one or other frontal. A very marked inion was noted in eight cases, naturally the male crania having the majority of 5 to 3.

Plagiocephaly was recorded in five cases, three male and two female, and one of the latter is reproduced in Plate XLI. The peculiar shape of forehead which may be best described as a "marked infantile type" was found in four crania all female; one of these otherwise normal skulls is depicted in Plate XVII. The great length of the English skull is not a little due to the frequency of protuberant occiputs*, and these have been especially noted in our second series. It is further emphasised by the frequency of almost every degree of bathrocephaly. Fifteen bathrocephalic skulls, 9 male and 6 female, were recorded, and an equally high percentage was found in our second series. In 7 out of the 15 cases, bathrocephaly was combined with a more or less numerous system of ossicles in the lambdoid suture (Merkel). Plates XLII—XLV give fairly good representations of two female (W. 7042 and W. 7059) markedly bathrocephalic skulls.

A *torus occipitalis* was noted in 13 skulls, 7 males and 6 females.

Turning now to the neighbourhood of the *foramen magnum* a careful examination was made of the condyles, and single or paired precondylar eminences noted in 14 crania, 5 male and 9 female. One female skull showed a third condyle with articular facet (W. 170), and one male (W. 111) had the anterior extremities of the condyles united by an osseous bridge. This is illustrated in the sketch below as it was found impossible to obtain a satisfactory photograph.

Plates XLVII and XLVIII illustrate cases of single and bilateral precondylar eminences. (*Condylus tertius?*)

Of other peculiarities we may note the rare case of the *hamulus lacrimalis* reaching the face figured in Plates XLIX and L; two cases of marked projection from hinder margin of external pterygoid plate (W. 85 ♂ and W. 86 ♀), two of the *porus crotaphitico-buccinatorius* of Hyrtl (W. 122 ♂ and W. 128 ♀), 5 cases of single or bilateral pterygospinous bridge, 3 male, 2 female; and isolated cases of imperfectly developed mandibular articulation (W. 57 ♀), *torus palatinus* (W. 149 ♀, see Plate XXIX), of subdivided *foramen ovale* (W. 173 ♂) and of markedly small right jugular foramen (W. 192 ♂ ? ?).

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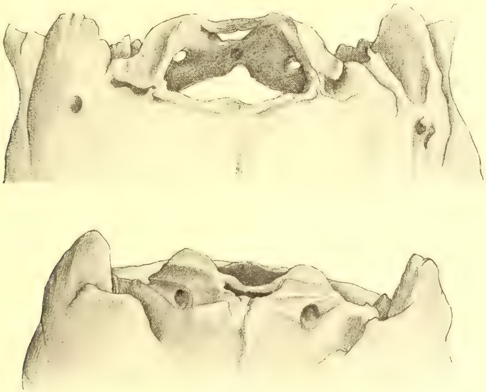
* Marked occipital projection occurred in four Whitechapel skulls, all four being female. Occipital flattening in one female skull.

(ii) *Ossicles and Wormian Bones.*

Ossicles of the bregma were recorded in 4 cases, 2 male and 2 female, and 1 case (associated with bathrocephaly) is depicted in Plate XXXII. Ossicles of the lambda occurred in 11 cases, 4 male and 7 female; cases of single and double ossicle of the lambda are reproduced in Plates XXXIII and XXXIV. Ossicles of the asterion occurred in 2 female and 1 male case, and of the pterion in 13 cases, 6 male and 7 female. There was one case of a frontosphenoidal ossicle (W. 212 ♂), 1 case of ossicles in the parietal notches of temporals (W. 7061 ♀) and 1 case of ossicles between occipital, parietal and mastoid (W. 31 ♂). Ossicles were recorded in the coronal suture in 3 cases, all male; in the sagittal suture, in 2 male and 2 female cases; in the lambdoid suture in 29 cases, of which 13 were male and 16 female; the lambdoid suture had a very irregular line* in the male skull W. 76; in the squamous suture there were 2 male and 2 female cases of ossicles and 1 case (W. 7109 ♂) of ossicles in the parietomastoid suture. On the whole upwards of 75 cases of ossicles were noted, 37 male and 38 female. We may therefore say that slightly more than 25 per cent. of English skulls have one or more anomalous ossicles.



W. 111. Osseous Bridge of Condyles.

(iii) *Anomalies of the Sutures.*

Twenty-four skulls were metopic, or a persistent frontal suture was found in 9 male and 15 female skulls. The mean breadth and minimum forehead breadth of these 24 skulls were compared with the means for the whole series with the following results:

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* Complicated sutures were also noticed in skulls 204 ♂ and 76 ♂.

Character	Male Skull		Female Skull	
	General	Metopic	General	Metopic
Maximum Breadth ...	141	142	135	135
Least Forehead Breadth	98	100	93	96

It would thus seem that a persistent frontal suture may allow of a two to three millimetres increase in the minimum forehead breadth, but probably does not influence the maximum cranial breadth.

We may perhaps note here that a metopic fontanelle occurred in one case, the male skull, W. 141.

Traces of a transverse-occipital suture were found in 3 cases and of an infra-orbital suture on the face in 2 cases, all males. In 1 female skull there was a division of the left parietal bone by a sinuous suture (W. 216), and in 3 cases, 1 male and 2 female, the apex of the occipital squama was produced upwards. Frontal process of temporal, single or bilateral, was noticed in 4 cases, 2 male and 2 female (see Plate XLVI) and a par-occipital process in 1 male skull (W. 192).

(iv) *Interparietals.*

As in the Esquimaux, the English skulls provide in both series a very considerable number of interparietals, in the Whitechapel series we have 5 male and 4 female. We may divide them into the simple interparietal, Plate XXXV, and the tripartite interparietal, Plate XXXVI. Skull W. 7096 is a good example of this although it is not as clearly shown in the plate as one might have wished. The complete tripartite interparietal consists as in skull W. 7096 of three parts. First the pentagonal shaped centre bone and then two triangular wings. These have been termed by Professor Thane the *os pentagonale* and the *ossa triangularia* respectively. Almost every form of this tripartite interparietal occurs in this English series. Thus we may have; (i) all three parts free as in Plate XXXVI. (ii) The *os pentagonale* fused and the *ossa triangularia* separate as in Plate XXXVII. (iii) The *os pentagonale* separate and the *ossa triangularia* fused as in Plate XL. (iv) The *os pentagonale* separate and the left *os triangulare* only separate, the right fused as in Plate XXXIX, or (v) the *os pentagonale* separate and the right *os triangulare* only separate, the left fused as in Plate XXXVIII. Cases of one *os triangulare* separate, and the other as well as the *os pentagonale* fused did not occur in this series. Still the series is so comprehensive and interesting that it seemed worth while to figure these interparietals fully, so that they may serve as standards for reference in other cases.

Taken as a whole the series appears to possess very considerable interest from the standpoint of special or "abnormal variations." The fact that the same high percentages are maintained in a second English series seems to show that we are dealing with something at anyrate characteristic of the Londoner. It would be of interest to enquire whether the proportions of special variations are greater in mixed races like the English, than in races of relatively purer character.

(9) *On the Variability of the English Skull.*

The numerical values of the variations are given in Table VII together with their probable errors.

Taking first the *capacity*, I extract various coefficients of variation from Pearson's *The Chances of Death*, Vol. I. pp. 328—349, for comparison with our series and the Naqadas.

	♂	♀
English*	8·28	8·68
Parisian French	7·36	7·10
Modern Italians	8·34	8·99
Modern Germans	7·74	8·19
Naqadas	7·72	6·92
Etruscans	9·58	8·54
Egyptian Mummies ...	8·13	8·29
Ainos	7·07	6·90

The variability of our series is high, but not quite so high as that of the Italians, and the female skull is slightly more variable than the male, the English in this respect resembling Italians and Germans.

Comparing the coefficients of variation of *length*, *breadth*, and *height* of the skull we find:

Race	Length		Breadth		Auricular Height	
	♂	♀	♂	♀	♂	♀
English ...	3·31	3·45	3·75	3·54	3·73	4·12
Bavarian† ...	3·37	3·57	3·89	3·39	4·47	3·91
French‡ ...	3·97	3·65	4·21	3·67	—	—
Naqada§ ...	3·17	3·14	3·29	3·45	3·86	3·54
Aino† ...	3·20	3·08	2·76	2·68	3·67	3·18

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[*] My own results are given; Pearson's figures were based on only 58 skulls—all that had been measured when he wrote.

[†] Alice Lee, *Phil. Trans.*, Vol. 196, A, p. 230.

[‡] Unpublished reductions of measurements in Broca's MS., by C. D. Fawcett.

[§] *Biometrika*, Vol. I. p. 438.

TABLE VII.

Variability of the English Skull.

Character	Male			Female		
	Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation
C	1476·94 ± 9·73	122·37 ± 6·88	8·28 ± ·47	1299·87 ± 8·51	112·80 ± 6·01	8·68 ± ·47
F	187·35 ± ·35	6·17 ± ·25	3·29 ± ·13	180·14 ± ·36	6·38 ± ·25	3·54 ± ·14
L′	187·76 ± ·45	5·64 ± ·32	3·00 ± ·17	180·07 ± ·57	6·33 ± ·40	3·52 ± ·22
L	189·06 ± ·36	6·27 ± ·25	3·31 ± ·13	180·36 ± ·35	6·22 ± ·25	3·45 ± ·14
B	140·67 ± ·31	5·28 ± ·22	3·75 ± ·15	134·68 ± ·27	4·77 ± ·19	3·54 ± ·14
B′	98·02 ± ·25	4·20 ± ·17	4·29 ± ·17	93·12 ± ·23	4·23 ± ·17	4·55 ± ·18
H	132·04 ± ·34	5·56 ± ·24	4·21 ± ·18	124·56 ± ·30	4·93 ± ·21	3·96 ± ·17
OH ...	114·59 ± ·25	4·28 ± ·18	3·73 ± ·15	109·21 ± ·25	4·50 ± ·18	4·12 ± ·16
LB ...	101·60 ± ·25	4·13 ± ·18	4·07 ± ·18	95·34 ± ·24	3·91 ± ·17	4·11 ± ·18
U	524·25 ± ·88	15·02 ± ·63	2·87 ± ·12	503·84 ± ·85	14·70 ± ·60	2·92 ± ·12
S	377·11 ± ·81	13·69 ± ·57	3·63 ± ·15	362·76 ± ·84	14·16 ± ·59	3·90 ± ·16
Q	307·93 ± ·72	11·40 ± ·51	3·70 ± ·16	293·97 ± ·71	11·67 ± ·50	3·97 ± ·17
G′H ...	70·17 ± ·30	3·86 ± ·21	5·50 ± ·30	65·93 ± ·40	4·71 ± ·28	7·14 ± ·43
GB ...	90·87 ± ·45	5·07 ± ·32	5·58 ± ·36	84·86 ± ·41	4·59 ± ·29	5·40 ± ·34
J	130·05 ± ·57	5·57 ± ·40	4·28 ± ·31	120·27 ± ·58	4·97 ± ·41	4·13 ± ·34
NH ...	51·22 ± ·20	2·60 ± ·14	5·08 ± ·27	48·68 ± ·22	2·70 ± ·16	5·55 ± ·32
NB ...	24·29 ± ·17	2·16 ± ·12	8·89 ± ·51	23·19 ± ·14	1·64 ± ·10	7·06 ± ·42
O_1L ...	43·06 ± ·15	1·81 ± ·11	4·20 ± ·25	41·17 ± ·13	1·45 ± ·09	3·53 ± ·22
O_1R ...	42·99 ± ·16	2·02 ± ·12	4·69 ± ·27	40·95 ± ·14	1·64 ± ·10	4·00 ± ·24
O_2L ...	33·46 ± ·15	1·88 ± ·11	5·61 ± ·33	33·59 ± ·12	1·45 ± ·09	4·31 ± ·26
O_2R ...	33·42 ± ·18	2·22 ± ·13	6·65 ± ·38	33·73 ± ·13	1·51 ± ·09	4·47 ± ·27
G_1	48·27 ± ·22	2·74 ± ·16	5·68 ± ·33	45·13 ± ·26	2·95 ± ·19	6·53 ± ·41
G_2	36·78 ± ·24	2·85 ± ·17	7·75 ± ·46	35·22 ± ·24	2·70 ± ·17	7·68 ± ·48
G_1' ...	44·66 ± ·21	2·53 ± ·14	5·67 ± ·33	41·53 ± ·22	2·53 ± ·16	6·10 ± ·38
GL ...	95·93 ± ·35	4·49 ± ·25	4·68 ± ·26	90·42 ± ·40	4·47 ± ·28	4·95 ± ·31
P ∠ ...	86°·09 ± ·33	3·92 ± ·24		87°·13 ± ·27	2·85 ± ·19	
A ∠ ...	73°·38 ± ·28	3·41 ± ·20		73°·90 ± ·29	3·31 ± ·21	
N ∠ ...	65°·19 ± ·29	3·52 ± ·20		64°·70 ± ·23	2·53 ± ·16	
B ∠ ...	41°·43 ± ·20	2·50 ± ·14		41°·39 ± ·27	2·98 ± ·19	
θ_1	28°·71 ± ·22	2·53 ± ·16		28°·11 ± ·24	2·51 ± ·17	
θ_2	12°·92 ± ·29	3·34 ± ·21		13°·13 ± ·34	3·60 ± ·24	
$100B/L'$ ...	75·17 ± ·24	2·97 ± ·17	3·95 ± ·23	74·62 ± ·27	3·01 ± ·19	4·03 ± ·26
$100B/L$ ...	74·34 ± ·19	3·26 ± ·14	4·38 ± ·18	74·73 ± ·18	2·98 ± ·12	3·99 ± ·17
$100H/L'$ ...	70·40 ± ·22	2·67 ± ·15	3·80 ± ·22	69·05 ± ·26	2·91 ± ·19	4·21 ± ·27
$100H/L$ ...	69·97 ± ·20	3·22 ± ·14	4·61 ± ·20	69·13 ± ·18	2·83 ± ·12	4·10 ± ·18
$100H/B$ ...	94·31 ± ·29	4·58 ± ·20	4·86 ± ·21	92·35 ± ·24	3·84 ± ·17	4·16 ± ·18
$100B/H$ ...	106·26 ± ·32	5·14 ± ·23	4·83 ± ·21	108·46 ± ·28	4·53 ± ·20	4·17 ± ·19
$100G'H/GB$	76·52 ± ·50	5·39 ± ·35	7·04 ± ·46	77·94 ± ·57	6·26 ± ·41	8·04 ± ·52
$100NB/NH$	47·55 ± ·37	4·58 ± ·26	9·64 ± ·55	47·79 ± ·33	3·90 ± ·23	8·16 ± ·49
$100O_2/O_1 : L$	77·86 ± ·32	3·78 ± ·23	4·86 ± ·29	81·70 ± ·38	4·23 ± ·27	5·18 ± ·33
$100O_2/O_1 : R$	77·69 ± ·38	4·66 ± ·27	6·00 ± ·35	82·46 ± ·37	4·33 ± ·26	5·25 ± ·32
$100G_2/G_1$ ...	76·26 ± ·55	6·40 ± ·39	8·39 ± ·52	77·69 ± ·62	6·62 ± ·44	8·52 ± ·57

The English skull closely resembles the Bavarian in variability of length and breadth, but there is a marked difference between the two as regards auricular height.

There are few data for comparison of the coefficients of variation of the *circumferential measurements*:

Race	Horizontal Circumference		Vertical Circumference	
	♂	♀	♂	♀
English	2·87	2·92	3·70	3·97
Bavarian*	2·86	3·09	—	—
Modern Badensians*	3·02	2·34	—	—
Row Grave German*	2·70	2·40	—	—
Naqada	2·54	2·27	3·32	2·72

Here again we observe that English and Bavarian males are equally variable, and that the English female, unlike the Naqada, is more variable than the male in both circumferences. Relatively to the horizontal circumferences the greater variability in the vertical circumference is in our series very marked.

Comparing *length of palate*, we have the following coefficients of variation:

Race	Length of Palate	
	♂	♀
English	5·65	6·53†
,,	5·67	6·10‡
Bavarian§	6·42	6·85
Naqada	6·49	7·41

The English and Bavarian differ considerably, but in all three races the female is the more variable.

For *profile angle*, we can compare the Bavarians and Naqadas:

Race	Standard deviation of Profile angle	
	♂	♀
English	3°·92	2°·85
Bavarians	2°·79	3°·59
Naqada	2°·87	3°·66

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* Pearson: *The Chances of Death*, Vol. I. pp. 356—7.

† Length includes *spina*.

‡ Length excludes *spina*.

§ Pearson: *The Chances of Death*, Vol. I. p. 328.

While Bavarian and Naqada are closely alike, and the female in both races is the more variable, in our series the position of the sexes is reversed, the male being the more variable.

Next we have to compare *indices*: the following table of standard deviations contains the chief material available for comparison, which I extract from C. D. Fawcett's paper, p. 440:

Race	*B/L*		*H/L*		*H/B*	
	♂	♀	♂	♀	♂	♀
English	3·26	2·98	3·22	2·83	4·58	3·84
Bavarian	3·50	2·97	—	—	—	—
French	4·43	4·19	3·53	3·67	4·74	4·31
Naqada	2·80	3·12	2·73	2·96	4·73	4·66
Row Grave Germans ...	2·28	2·35	—	—	—	—
Aino	2·41	2·54	—	—	—	—

Here again, so far as a comparison is possible, it appears that the variability of the English skulls is nearly the same as that of the Bavarian. It is to be noted, too, that in all three indices, the English female is less variable than the male.

For the remaining indices, the comparative data are meagre. We find the following standard deviations:

Race	Upper Face Index		Orbital Index		Nasal Index	
	♂	♀	♂	♀	♂	♀
English ...	5·39	6·26	*L* 3·78 *R* 4·66	4·23 4·33	4·58	3·90
Bavarian* ...	3·26	3·33	6·66	5·22	4·43	4·61
Naqada ...	4·52	4·15	*L* 5·06 *R* 5·00	4·57 4·78	4·18	4·86

These figures show marked diversity of results. As compared with the Bavarians, the English have much greater variability in upper face index and much less in orbital index; and while in upper face index and nasal index the Bavarian female has nearly the same variability as the male, the English female is more variable in the former, and less so in the latter. In orbital index, too, the comparative variability of the two sexes is remarkable, and is complicated by the marked difference between the standard deviations of the two eyes in the English male.

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* Pearson: *The Chances of Death*, Vol. I. pp. 325—328.

In the following characters I will compare the variability of our series with that of the Naqadas only, there being practically no material available for other races, and for this purpose I use *coefficients of variation.*

	English		Naqadas	
	♂	♀	♂	♀
B' ...	4·29	4·55	5·29	4·47
H ...	4·21	3·96	3·98	3·66
LB ...	4·07	4·11	4·88	4·68
S ...	3·63	3·90	3·19	3·51
$G'H$ ...	5·50	7·14	6·08	6·87
GB ...	5·58	5·40	5·18	4·77
J ...	4·28	4·13	4·16	4·77
NH ...	5·08	5·55	6·13	6·81
NB ...	8·89	7·06	7·89	7·28
O_1L ...	4·20	3·53	4·97	5·30
O_1R ...	4·69	4·00	5·02	5·38
O_2L ...	5·61	4·31	7·06	6·58
O_2R ...	6·65	4·47	7·27	6·85
G_2 ...	7·75	7·68	9·29	8·55
GL ...	4·68	4·95	4·84	5·09
$100G_2/G_1$...	8·39	8·52	10·23	8·20

In the midst of great diversity, some features emerge that are common to both races; e.g. the great variability of upper face height in females, of the breadth of the nose and palate in males and females, also of palatal index in both sexes. It is also noticeable that the variability of orbital height is much greater than that of orbital length in the males of both races.

I will conclude this part of the subject by dealing with the variability of the mandibles, for which I give a separate table as before:

TABLE VIII.

Variability of English Mandibles. Male and Female.

Character	Mean	Standard Deviation	Coefficient of Variation
W_1	113·21 ± ·41	6·31 ± ·29	5·57 ± ·26
W_2	95·40 ± ·46	8·31 ± ·32	8·71 ± ·34
h_1	30·76 ± ·21	3·61 ± ·15	11·73 ± ·49
f	43·67 ± ·14	2·72 ± ·10	6·23 ± ·23

Comparing the coefficients of variation with those of the Naqada race, we find:

Character	English	Naqada		
	Male and Female	Male	Female	Male and Female
W_1	5·57	7·46	6·77	7·34
W_2	8·71	7·62	7·19	8·11
h_1	11·73	9·93	8·47	9·40
f	6·23	5·73	5·31	5·72

From these figures we may conclude that the English mandibles are more variable than the Naqadas in all the characters except W_1.

Summing up generally for the consideration of the variability, it is clear that our Whitechapel skulls have very much the same general degree of variation as the Bavarian. There is certainly no marked difference which would allow us to assert that this group is less homogeneous than the Altbayern of Professor Ranke. It would indeed be rash to assert that they are more or less variable than the Naqada. Far more data must be reduced for variability before we can see clearly where we stand. But when once tables of variation have been made out for 30 or 40 fairly long series of skulls we shall probably get a fairly good scale of relative homogeneity for many characters and so be able more easily to detect marked heterogeneity in cranial series.

(10) *On the Nature of the Frequency Distribution.*

I will now discuss the variability of the series graphically and analytically, using the notation of Pearson's memoir on Skew Variation*. I have selected, for both sexes, the 12 characters dealt with by C. D. Fawcett†, and have added a thirteenth, viz., B', or least breadth of forehead, but I do not propose to plot the 26 skew curves representing the distributions of these characters, because in most cases the normal curve represents the distribution with sufficient accuracy for all practical purposes, as I shall now proceed to show.

The following table gives the chief analytical constants of the skew curves for the 13 selected characters. The second column gives the number of skulls on which the calculation is based; the third shows the unit in terms of which the 2nd, 3rd, and 4th moments (μ_2, μ_3 and μ_4) are calculated; after the moments follow columns giving β_1, $\sqrt{\beta_1}$ with its probable error, β_2 with its probable error, the difference between β_2 and the number 3, and the "criterion" $6+3\beta_1-2\beta_2$ with its probable error; the next three columns give the mean, the "mode," or value for which the frequency is greatest, and the "skewness," or ratio of distance between mode and mean to standard deviation, with its probable error[*].

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* *Phil. Trans.* Vol. 186, A, pp. 343—414.

† *Loc. cit.*, p. 442.

Dealing first with the skewness, we observe that in 13 cases it is positive, or the mean is greater than the mode, and in 13 cases it is negative, or the mean is less than the mode. Further, in only two of the 13 cases of positive skewness, viz., *NB* ♂ and *H*/*L* ♀, and in only two of the 13 cases of negative skewness, viz., *H* ♂ and *G'H* ♂, can the skewness be considered as certainly significant when compared with the probable error; of the remaining cases two of the negative skewnesses, *L* ♀ and *U* ♀, and one of the positive, *NH* ♀, are perhaps significant; the rest are certainly insignificant. We cannot, therefore, conclude, as C. D. Fawcett was able to do with her Naqada skulls[†], that if the mean and the mode do not coincide, the mean will be almost invariably greater than the mode. In our series if we were to draw the curves, the mean would be found in half the number of the curves to be less, and in the other half to be greater than the mode.

We will next examine the constants β_1 and β_2. If $\beta_1 = 0$ and $\beta_2 = 3$, the curve representing the distribution is the normal curve, and, therefore, in order to see how far the skew curves diverge from the normal we must first observe how much β_1 and β_2 differ from zero and 3 respectively, and then estimate the significance of the difference by comparing it with the respective probable errors. Columns 8, 9 and 10 enable us to make the comparison. Taking the $\sqrt{\beta_1}$ column first, we note that in only four cases out of the 26 is $\sqrt{\beta_1}$ certainly significant when compared with its probable error, and these four are precisely those which we have had occasion to notice as exceptional in regard to skewness, viz., *H* ♂, *G'H* ♂, *NB* ♂ and *H*/*L* ♀. In six cases $\sqrt{\beta_1}$ is greater, but not more than $1\frac{1}{2}$ times greater than the probable error, and in the remaining 16 cases $\sqrt{\beta_1}$ is less, sometimes very much less than the probable error.

A comparison of the $3-\beta_2$ column with the probable error of β_2 leads to similar results; in only three cases is the difference certainly significant; in the most unfavourable of the remaining cases the difference is less than twice the probable error. Similar remarks apply to a comparison of the criterion with its probable error.

Our examination of the constants of the curves thus confirms C. D. Fawcett's conclusion[‡]: *With series of skull measurements such as the present, which are long for the craniologist, if short for the statistician, we shall reach for most practical purposes adequate graphical representations of the frequency by using the normal curve of deviations,* $y = y_0 e^{-x^2/2\sigma^2}$.

This being the case, I do not propose to calculate and plot any of the skew curves, but will content myself with tracing two normal curves, the one repre-

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[*] For the formulae for calculating these probable errors, see Pearson, *Phil. Trans.* Vol. 198, A, p. 278.

[†] C. D. Fawcett on p. 443 says only 5 out of 24 cases have *negative* skewness, her table shows 6, but this does not affect her argument.

[‡] *Loc. cit.* p. 443.

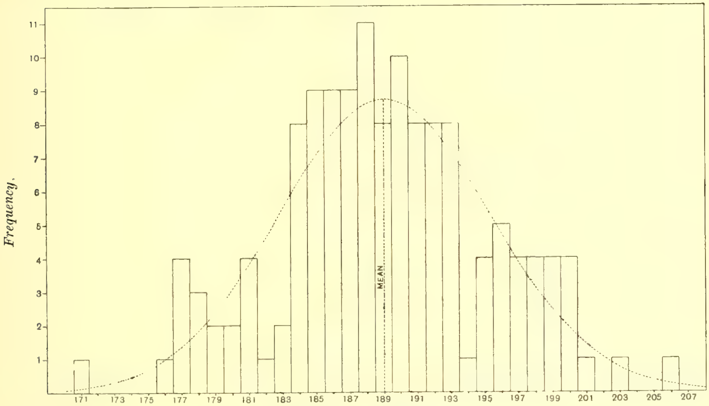
TABLE IX.

Analytical Constants of Curves.

Character	No.	Unit	μ_2	μ_3	μ_4	β_1	$\sqrt{\beta_1}$	β_2	$3-\beta_2$	Criterion	Mean	Mode	Skewness	Distance of Mean from Mode
L ♂ ...	*137*	1 mm.	39·2709	− 6·4413	4562·103	·00068	·0262 ± ·1411	2·9582 ± ·2823	·0418	·0857 ± ·5646	189·06	189·14	− ·0135 ± ·0706	− ·0844 ± ·4426
L ♀ ...	*140*	1 mm.	38·6768	− 52·3296	4650·972	·04733	·2175 ± ·1396	3·1091 ± ·2793	− ·1091	− ·0763 ± ·5585	180·36	181·02	− ·1061 ± ·0698	·6600 ± ·4341
B ♂ ...	*135*	1 mm.	27·8697	− 23·8924	3349·490	·02637	·1624 ± ·1422	4·3123 ± ·2844	− 1·3123	− 2·5456 ± ·5688	140·67	140·92	− ·0479 ± ·0711	− ·2527 ± ·3754
B ♀ ...	*140*	1 mm.	22·7776	4·7849	1391·762	·00194	·0440 ± ·1396	2·6825 ± ·2793	·3175	·6407 ± ·5585	134·68	134·54	·0284 ± ·0698	·1357 ± ·3329
B′ ♂ ...	*132*	1 mm.	17·6813	5·7205	982·701	·00592	·0769 ± ·1438	3·1433 ± ·2876	− ·1433	− ·2689 ± ·5752	98·02	97·87	·0354 ± ·0719	·1487 ± ·3020
B′ ♀ ...	*147*	1 mm.	17·9237	− 2·2559	913·379	·00088	·0297 ± ·1363	2·8431 ± ·2725	·1569	·3164 ± ·5451	93·12	93·19	− ·0166 ± ·0682	− ·0742 ± ·2885
H ♂ ...	*122*	1 mm.	30·9068	− 52·0149	2676·625	·09164	·3027 ± ·1496	2·8021 ± ·2992	·1979	·6708 ± ·5983	132·04	133·13	− ·1969 ± ·0748	− 1·0946 ± ·4159
H ♀ ...	*124*	1 mm.	24·3409	21·5954	1944·593	·03234	·1798 ± ·1484	3·2821 ± ·2967	− ·2821	− ·4672 ± ·5935	124·56	124·17	·0783 ± ·0742	·3862 ± ·3658
OH ♂ ...	*135*	1 mm.	18·3062	·8921	864·324	·00013	·0114 ± ·1422	2·5792 ± ·2844	·4208	·8421 ± ·5688	114·59	114·56	·0082 ± ·0711	·0349 ± ·3043
OH ♀ ...	*143*	1 mm.	20·2173	− 4·9820	1153·463	·00300	·0548 ± ·1382	2·8220 ± ·2764	·1780	·3650 ± ·4528	109·21	109·35	− ·0313 ± ·0691	− ·1408 ± ·3109
U ♂ ...	*131*	3 mm.	25·0799	16·8212	1930·670	·01793	·1339 ± ·1443	3·0694 ± ·2886	− ·0694	− ·0850 ± ·5772	524·25	523·27	·0651 ± ·0722	·9784 ± 1·0844
U ♀ ...	*136*	3 mm.	24·0096	− 22·2282	1799·619	·03570	·1889 ± ·1417	3·1218 ± ·2834	− ·1218	− ·1366 ± ·5668	503·82	505·15	− ·0904 ± ·0709	− 1·3294 ± 1·0422
S ♂ ...	*131*	3 mm.	20·8174	·7925	1257·431	·00007	·0084 ± ·1443	2·9021 ± ·2886	·0979	·1959 ± ·5772	377·11	377·04	·0045 ± ·0722	·0613 ± ·9884
S ♀ ...	*130*	3 mm.	22·2711	− 4·9740	1469·983	·00224	·0473 ± ·1449	2·9637 ± ·2898	·0363	·0794 ± ·5796	362·76	363·10	− ·0243 ± ·0725	− ·3441 ± 1·0266
Q ♂ ...	*115*	3 mm.	14·4510	− 10·8254	740·293	·03883	·1970 ± ·1541	3·5449 ± ·3082	− ·5449	− ·9734 ± ·6164	307·93	308·80	− ·0759 ± ·0772	− ·8661 ± ·8801
Q ♀ ...	*122*	3 mm.	15·1406	− 3·8293	704·922	·00422	·0650 ± ·1496	3·0751 ± ·2992	− ·0751	− ·1375 ± ·5983	293·97	294·33	− ·0311 ± ·0748	− ·3627 ± ·8729
G′H ♂ ...	*75*	1 mm.	14·9222	− 30·1774	762·216	·27407	·5235 ± ·1908	3·4230 ± ·3816	− ·4230	− ·0238 ± ·7632	70·17	71·17	− ·2598 ± ·0954	− 1·0037 ± ·3682
G′H ♀ ...	*62*	1 mm.	22·1544	− 14·6309	1244·756	·01968	·1403 ± ·2098	2·5361 ± ·4196	·4639	·9869 ± ·8392	65·93	66·45	− ·1090 ± ·1049	− ·5131 ± ·4941
NH ♂ ...	*79*	1 mm.	6·7727	·8949	155·477	·00258	·0508 ± ·1859	3·3896 ± ·3718	− ·3896	− ·7714 ± ·7436	51·22	51·17	·0204 ± ·0930	·0532 ± ·2418
NH ♀ ...	*67*	1 mm.	7·3137	4·5942	161·147	·05395	·2323 ± ·2018	3·0126 ± ·4036	− ·0126	·1366 ± ·8072	48·68	48·35	·1216 ± ·1009	·3290 ± ·2724
NB ♂ ...	*70*	1 mm.	4·6636	8·6651	121·478	·74025	·8604 ± ·1975	5·5854 ± ·3950	− 2·5854	− 2·9500 ± ·7900	24·28	23·73	·2550 ± ·0988	·5506 ± ·2134
NB ♀ ...	*64*	1 mm.	2·6832	·0200	16·684	·00002	·0045 ± ·2065	2·3173 ± ·4130	·6827	1·3654 ± ·8260	23·20	23·19	·0047 ± ·1033	·0077 ± ·1694
100*B*/*L* ♂	*131*	½ point	42·5105	10·2971	6276·633	·00138	·0372 ± ·1443	3·4732 ± ·2886	− ·4732	− ·9423 ± ·5772	74·34	74·29	·0144 ± ·0722	·0469 ± ·2354
100*B*/*L* ♀	*130*	½ point	35·5465	13·3830	3297·173	·00399	·0632 ± ·1449	2·6094 ± ·2898	·3906	·7931 ± ·5796	74·73	74·60	·0440 ± ·0725	·1312 ± ·2160
100*H*/*L* ♂	*120*	½ point	41·5789	− 20·4340	6595·303	·00581	·0762 ± ·1508	3·8149 ± ·3016	− ·8149	− 1·6124 ± ·6032	69·97	70·05	− ·0259 ± ·0754	·0834 ± ·2428
100*H*/*L* ♀	*117*	½ point	32·1325	74·3841	2883·140	·16677	·4084 ± ·1527	2·7924 ± ·3054	·2076	·9155 ± ·6108	69·13	68·28	·2986 ± ·0764	·8462 ± ·2162

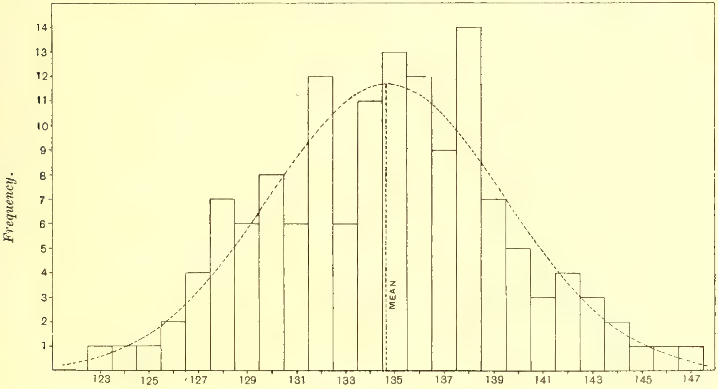
senting the distribution of L ♂, the other that of B ♀ (Diagrams I. and II.). As usual, the y unit is one individual per unit of x, and the x unit is 1 mm. The scale of absolute frequency indicated on the vertical to the left of the diagram gives y.

Diagram I.



Length of Head in Male Crania.

Diagram II.



Breadth of Head in Female Crania.

Dealing first with the $L♂$ normal curve—the general equation $y = y_0 e^{-x^2/2\sigma^2}$, where $y_0 = \dfrac{137}{\sigma\sqrt{2\pi}}$ and $\sigma = 6{\cdot}26665$, becomes $y = 8{\cdot}7216 e^{-{\cdot}01273x^2}$, and the origin is at 189·06 mm. I will now apply Pearson's test of goodness of fit to the curve*. The following table shows the observed frequencies (m_r'), the frequencies calculated from the curve (m_r), and the ratio $(m_r - m_r')^2/m_r$:

mm.	Observed	Calculated	$\dfrac{(m_r - m_r')^2}{m_r}$
176 and under	2	3·1	·39
177	4	1·4	4·83
178	3	1·8	·80
179	2	2·4	·07
180	2	3·1	·39
181	4	3·8	·01
182	1	4·6	2·82
183	2	5·5	2·23
184	8	6·3	·46
185	9	7·1	·51
186	9	7·7	·22
187	9	8·2	·08
188	11	8·6	·67
189	8	8·7	·06
190	10	8·6	·23
191	8	8·3	·01
192	8	7·8	·005
193	8	7·1	·11
194	1	6·4	4·57
195	4	5·6	·46
196	5	4·7	·02
197	4	3·9	·003
198	4	3·1	·26
199	4	2·5	·90
200	4	1·9	2·32
201	1	1·4	·11
202 and over	2	3·4	·58
Totals	137	137	23·12

Here the number of groups is 27, and $\chi^2 = 23{\cdot}12$, and turning to Elderton's Tables† we find for $n' = 27$ and $\chi^2 = 23$, that $P = {\cdot}632947$; that is, if our series of English skulls obeyed the "normal" frequency distribution for the character L the frequency polygon would be more "peaked" in about 63 out of 100 trial samples of 137 skulls each. The normal curve, therefore, fits the observations quite satisfactorily.

It is unnecessary to discuss the normal curve for $B♀$ in great detail; its equation is $y = 11{\cdot}7026 e^{-{\cdot}02195x^2}$, with centre at 134·68 mm. In this case $\chi^2 = 9{\cdot}89$

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* *Phil. Mag.* Vol. L. pp. 157—175 (July, 1900), and *Biometrika*, Vol. I. p. 155.

† *Biometrika*, Vol. I. p. 161.

and $n' = 25$, and therefore from Elderton's Table $P = \cdot 99$; that is, in 99 out of every 100 trials we should get a more peaked polygon than the one representing the actual observations. The fit may therefore be considered perfect.

These two illustrations show that we must be most cautious in using the peaked or multimodal appearance of a polygon representing the distribution of a character in a short series of crania, as an argument in favour of heterogeneity of race, seeing that the peaks may well be due entirely to random sampling*.

In view of Pearson's article in *Biometrika*, Vol. II. Part III. on "Professor Aurel von Török's attack on the Arithmetical Mean," I have added to Table IX. a column showing the difference between the mean and the mode, and its probable error. Looking at the absolute values of the difference, we observe that in only three cases does it exceed 1 mm. In most of the remaining cases it is only a very small fraction of a millimetre or a point, and when compared with its probable error is quite insignificant.

(11) *On the Correlation of Cranial Characters.*

In addition to the 27 pairs of characters which C. D. Fawcett exhibited in her Table XIII.†, I have selected seven other pairs of important characters, and in arriving at the 34 coefficients of correlation I have calculated the sum of the products of the pairs of measurements, instead of forming correlation tables; by this method, somewhat greater accuracy is attained, especially in dealing with circumferences and indices. Thus, let a, b be the measurements of two characters in an individual; M_1 and M_2 the means, and σ_1 and σ_2 the standard deviations of the characters, N the total number of individuals; then r, the coefficient of correlation, $= S(xy)/N\sigma_1\sigma_2$, and

$$\begin{aligned}\frac{S(xy)}{N} &= S(M_1 - a)(M_2 - b)/N \\ &= S(M_1M_2 - aM_2 - bM_1 + ab)/N \\ &= \{NM_1M_2 - M_2S(a) - M_1S(b) + S(ab)\}/N \\ &= \frac{S(ab)}{N} - M_1M_2.\end{aligned}$$

The following table gives the coefficients of correlation, and includes C. D. Fawcett's Table XIII. for the sake of comparison.

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* See C. D. Fawcett, *loc. cit.* p. 454, and Pearson in *Biometrika*, Vol. II. pp. 341—343, where he deals with greatest forehead breadth and greatest skull breadth in 2000 Hungarian skulls.

† *Loc. cit.* p. 455.

TABLE X.

Correlation of Cranial Characters.

Pair of Characters	Whitechapel English				Naqadas			
	No.	♂	No.	♀	No.	♂	No.	♀
L & H	*120*	·255 ± ·058	*117*	·425 ± ·051	*134*	·489 ± ·044	*163*	·283 ± ·048
L & B	*131*	·240 ± ·055	*130*	·350 ± ·052	*139*	·344 ± ·050	*183*	·143 ± ·049
B & H	*116*	·233 ± ·059	*115*	·340 ± ·056	*129*	·273 ± ·055	*163*	·119 ± ·052
C & H	*72*	·501 ± ·059	*78*	·600 ± ·049	*86*	·642 ± ·043	*114*	·519 ± ·046
C & B	*72*	·631 ± ·048	*80*	·646 ± ·044	*89*	·434 ± ·058	*123*	·532 ± ·044
C & L	*72*	·597 ± ·051	*78*	·691 ± ·040	*89*	·501 ± ·054	*123*	·599 ± ·039
C & Q	*72*	·812 ± ·027	*79*	·744 ± ·034	*84*	·656 ± ·042	*118*	·603 ± ·039
C & U	*72*	·820 ± ·026	*80*	·848 ± ·021	*84*	·681 ± ·040	*115*	·723 ± ·030
C & S	*72*	·714 ± ·039	*77*	·811 ± ·026	—	—	—	—
C & $(S \times U \times Q)$	*72*	·879 ± ·018	*77*	·886 ± ·016	—	—	—	—
Q & S	*108*	·666 ± ·036	*109*	·581 ± ·043	—	—	—	—
U & S	*124*	·804 ± ·021	*124*	·827 ± ·019	—	—	—	—
U & Q	*110*	·720 ± ·031	*114*	·615 ± ·039	*84*	·512 ± ·054	*115*	·454 ± ·050
O_1 & O_2 (L)	*63*	·535 ± ·061	*57*	·161 ± ·087	*81*	·434 ± ·061	*108*	·477 ± ·050
O_1 & O_2 (R)	*68*	·462 ± ·064	*62*	·244 ± ·080	*82*	·405 ± ·062	*112*	·510 ± ·047
NB & NH	*70*	·146 ± ·079	*64*	·182 ± ·081	*84*	·343 ± ·065	*116*	·125 ± ·061
G_1 & G_2	*61*	·214 ± ·082	*51*	·255 ± ·088	*73*	·202 ± ·076	*105*	·501 ± ·049
$G'H$ & GB	*53*	·189 ± ·089	*54*	·225 ± ·087	*77*	·385 ± ·065	*101*	·479 ± ·050
H/L & NB/NH	*65*	·256 ± ·078	*57*	− ·141 ± ·088	*71*	− ·050 ± ·080	*107*	− ·132 ± ·064
H/L & O_2/O_1 (L)	*58*	− ·325 ± ·079	*53*	− ·057 ± ·092	*70*	·175 ± ·078	*100*	− ·002 ± ·067
H/L & O_2/O_1 (R)	*63*	− ·243 ± ·080	*56*	·102 ± ·089	*73*	·170 ± ·077	*102*	− ·016 ± ·067
H/L & G_2/G_1	*56*	− ·121 ± ·089	*44*	− ·168 ± ·099	*59*	·148 ± ·086	*87*	− ·041 ± ·072
B/L & NB/NH	*66*	·177 ± ·080	*57*	− ·212 ± ·085	*75*	− ·148 ± ·076	*110*	− ·050 ± ·064
B/L & O_2/O_1 (L)	*59*	− ·159 ± ·086	*52*	·003 ± ·093	*72*	·106 ± ·079	*102*	− ·085 ± ·066
B/L & O_2/O_1 (R)	*65*	− ·079 ± ·083	*54*	− ·001 ± ·092	*74*	·165 ± ·076	*104*	− ·036 ± ·066
B/L & G_2/G_1	*56*	− ·189 ± ·087	*43*	·056 ± ·102	*60*	·317 ± ·078	*88*	·109 ± ·071
NB/NH & O_2/O_1 (L)	*60*	− ·301 ± ·079	*55*	− ·186 ± ·088	*77*	− ·276 ± ·071	*111*	− ·263 ± ·060
NB/NH & O_2/O_1 (R)	*60*	− ·456 ± ·069	*58*	− ·258 ± ·083	*76*	− ·323 ± ·069	*113*	− ·279 ± ·059
NB/NH & G_2/G_1	*56*	·081 ± ·089	*50*	− ·014 ± ·095	*67*	− ·194 ± ·079	*97*	·026 ± ·068
G_2/G_1 & O_2/O_1 (L)	*52*	− ·230 ± ·089	*43*	− ·052 ± ·103	*62*	·118 ± ·085	*93*	·108 ± ·069
G_2/G_1 & O_2/O_1 (R)	*49*	− ·221 ± ·092	*44*	− ·115 ± ·100	*65*	·177 ± ·081	*94*	·216 ± ·066
B & B'	*127*	·432 ± ·049	*137*	·367 ± ·050	*52*	·111*	—	—
B & J	*43*	·468 ± ·080	*32*	·414 ± ·099	*52*	·044*	—	—
B' & J	*42*	·620 ± ·064	*33*	·497 ± ·088	*52*	·569*	—	—

This table shows that our series of English skulls agrees with that of the Naqadas in having a low degree of correlation between most of the characters selected for examination. In this respect the skull differs markedly from the long bones of the leg and arm†. For example, it has been found that in 100 French male and female skeletons the coefficients of correlation between the long bones

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* *Biometrika*, Vol. II. p. 350.

† Fawcett, *loc. cit.* p. 455, and Lee and Pearson, *Phil. Trans.* Vol. 196, pp. 228, 229.

TABLE XI.

Series	L and H				L and B				B and H			
	♂		♀		♂		♀		♂		♀	
	No.		No.		No.		No.		No.		No.	
Whitechapel English ...	*120*	·255 ± ·058	*117*	·425 ± ·051	*131*	·240 ± ·055	*130*	·350 ± ·052	*116*	·233 ± ·059	*115*	·340 ± ·056
French ‡	*860*	·294 ± ·022	*340*	·132 ± ·036	*860*	·089 ± ·024	*340*	− ·042 ± ·037	*860*	·224 ± ·023	*340*	·229 ± ·035
German §	*100*	[− ·096 ± ·067]*	*99*	[·314 ± ·061]*	*100*	·286 ± ·062	*99*	·488 ± ·052	*100*	[·072 ± ·067]*	*99*	[·276 ± ·063]*
English (Criminals) ‖ ...	—	—	—	—	*3000*	[·402 ± ·010]†	—	—	—	—	—	—
English (Middle Classes) ‖	—	—	—	—	*1000*	[·345 ± ·019]†	—	—	—	—	—	—
Aino §	*87*	[·501 ± ·054]*	*63*	[·349 ± ·075]*	*87*	·432 ± ·059	*63*	·376 ± ·073	*87*	[·345 ± ·064]*	*63*	[·178 ± ·082]*
Naqada ¶	*134*	·489 ± ·044	*163*	·283 ± ·048	*139*	·344 ± ·050	*183*	·143 ± ·049	*129*	·273 ± ·055	*163*	·119 ± ·052

* Auricular and not total height used and so not properly comparable.

† Measurements on living head and not skull.

‡ See footnote, p. 239.

§ See A. Lee: *Phil. Trans.* Vol. 196, A, p. 231.

‖ Macdonell: *Biometrika*, Vol. I. pp. 181 and 188.

¶ C. D. Fawcett: *Biometrika, loc. cit.*, p. 455.

ranged from ·74 to ·98[*]. A similarly high correlation has also been shown to exist between the first finger joints, the coefficients ranging from ·82 to ·91[†].

I will now examine in detail the results shown in the Table, and compare them with the results obtained for other races, incorporating in my tables the comparable material which C. D. Fawcett collected in her Tables XV., XVI. and XVII.

Length, Breadth and Height Correlations.

In the English series we observe that the females are much more highly correlated than the males in all three pairs of characters. In this respect they agree with the German series, but here the comparison is unsatisfactory so far as height is concerned, the German height being auricular, the English basio-bregmatic. English also agree with Naqada in so far as L and H is the most closely associated pair in both races. On the other hand, it is the males who are the more highly correlated throughout in Ainos and Naqadas, and also in French except for the pair B and H, where the sexes agree; here again, however, it must be noted that in the case of the Ainos we are dealing with the auricular height.

In absolute value of the correlation coefficients we observe that our series agrees fairly closely with the French in the pairs L and H♂ and B and H♀ and with the German in L and B♂, but in no others.

Correlation of Breadths.

Little has hitherto been done in working out the correlation between cephalic (B), frontal (B') and bizygomatic (J) breadths: the following table gives all the material that I have been able to find:

TABLE XII.

Correlation of Head Breadths.

Race	B and B'		B and J		B' and J	
	♂	♀	♂	♀	♂	♀
English	·432	·367	·468	·414	·620	·497
Naqadas [‡]	·111	—	·044	—	·569	—
Theban Mummies [‡]	·298	—	·250	—	·342	—
Oraon Tribe [‡] (living head)	·587	—	·409	—	·554	—

There is fairly close agreement between English skulls and living Oraons in all three correlation coefficients. The correlation between frontal and bizygomatic breadths is very much the same in Naqadas as in English and Oraons, and in all four races it is greater than that between cephalic and bizygomatic breadths. The low correlation between B and B', and B and J in the two Egyptian series, especially in the Naqadas, is to be noted.

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[*] Lee and Pearson: *R. S. Proc.* Vol. 61, pp. 349, 350.

[†] Whiteley and Pearson: *R. S. Proc.* Vol. 65, p. 130. See also Lewenz and Whiteley: *Biometrika*, Vol. I. pp. 345—60.

[‡] *Biometrika*, Vol. II. pp. 349—351.

In the English, the female is less highly correlated than the male.

Correlations of Capacity.

TABLE XIII.

Capacity and Height, Breadth and Length.

Race	C and H				C and B				C and L			
	♂		♀		♂		♀		♂		♀	
	No.		No.		No.		No.		No.		No.	
English	72	·501 ± ·059	78	·600 ± ·049	72	·631 ± ·048	80	·646 ± ·044	72	·597 ± ·051	78	·691 ± ·040
Naqada	86	·642 ± ·043	114	·519 ± ·046	89	·434 ± ·058	123	·532 ± ·044	89	·501 ± ·054	123	·599 ± ·039
German	100	·243 ± ·064	99	·451 ± ·054	100	·672 ± ·037	99	·706 ± ·034	100	·515 ± ·050	99	·687 ± ·037
Aino	76	·544 ± ·054	52	·521 ± ·068	76	·561 ± ·053	52	·502 ± ·070	76	·893 ± ·016	52	·663 ± ·053
Sioux	57	·440 ± ·070	—	—	57	·67 ± ·05	—	—	57	·54 ± ·06	—	—
Means		·48		·52		·60		·59		·61		·66

There is no striking difference between the sexes in our series, such as exists between German ♂ and ♀ in the pair C and H, and Aino ♂ and ♀ in C and L, but here again the English female is more highly correlated than the male, in this respect again agreeing with the Germans throughout, and also with the Naqadas except in the pair C and H. In Ainos the position is reversed, the male being the more highly correlated.

We have only Naqadas and Theban mummies for comparison in the case of capacity and circumferences.

TABLE XIV.

Capacity and Circumferences.

Race	C and U				C and Q				C and S			
	♂		♀		♂		♀		♂		♀	
	No.		No.		No.		No.		No.		No.	
English	72	·820 ± ·026	80	·848 ± ·021	72	·812 ± ·027	79	·744 ± ·034	72	·714 ± ·039	77	·811 ± ·026
Naqada	84	·681 ± ·040	115	·723 ± ·030	84	·656 ± ·042	118	·603 ± ·039	—	—	—	—
Theban Mummies	202	·813 ± ·016	96	·826 ± ·022	202	·788 ± ·018	96	·673 ± ·038	—	—	—	—

The correlation in the English is remarkably close to that in the Thebans, and considerably greater than that in the Naqadas. In the pair C and U, the female is the more highly correlated, in the pair C and Q the male has the advantage in all three series, but there is no marked preponderance in favour of either sex except in Theban C and Q. Unfortunately there is as yet no published material available for further comparison. In the English, the female is considerably the more highly correlated in C and S, but in the pair C and the product USQ the correlation of the sexes is practically equal.

Correlation of Circumferences.

The only material available for comparison is Naqada and Theban Q and U, which are included in Table XV.

TABLE XV.

Race	Q and S				U and S				U and Q			
	♂		♀		♂		♀		♂		♀	
	No.		No.		No.		No.		No.		No.	
English	*108*	·666 ± ·036	*109*	·581 ± ·043	*124*	·804 ± ·021	*124*	·827 ± ·019	*110*	·720 ± ·031	*114*	·615 ± ·039
Naqada	—	—	—	—	—	—	—	—	*84*	·512 ± ·054	*115*	·454 ± ·050
Theban Mummies	—	—	—	—	—	—	—	—	*202*	·665 ± ·027	*96*	·625 ± ·042

We again notice that English and Thebans are very much alike, this time in regard to the correlation of U and Q, both having a considerably higher correlation than the Naqadas; in all three series, the female has the higher correlation for this pair of characters. In English, for the pair S and U, the female correlation preponderates; for S and Q, the male, just as we found in the pairs C and U and C and Q.

Orbital, Facial and Palatal Measurements.

Only the Naqada results are available for comparison. In our series the marked difference between the sexes in the correlation of height and breadth of orbit will be noted: in the left orbit, the correlation is more than three times as great, in the right orbit about twice as great, in the males as in the females. The nose, palate and face correlations are small in both sexes, and their probable errors are comparatively large.

In these respects the English differ very markedly from the Naqadas. In the latter, the correlation of height and breadth of orbit is much the same for both eyes and for both sexes, and the palatal and facial correlations are considerable in females. The difference may be partly due to the different methods of measuring the English and Naqada orbit and palate, but in nasal and facial correlations also, where the methods adopted were the same, there is a marked contrast between the two races.

Index Correlations.

The following Table shows how the chief index characters are associated with each other in the two series, English and Naqada.

TABLE XVI.

Character	English		Naqadas	
	♂	♀	♂	♀
Chamaecephaly	Leptorrhiny *L.* Hypsiconchy *R.* Hypsiconchy Brachystaphyly	Platyrrhiny Hypsiconchy[*] Chamaeconchy Brachystaphyly	Platyrrhiny Chamaeconchy Chamaeconchy Leptostaphyly	Platyrrhiny Hypsiconchy[†] Hypsiconchy[†] Brachystaphyly[*]
Brachycephaly	Platyrrhiny *L.* Chamaeconchy *R.* Chamaeconchy Leptostaphyly	Leptorrhiny Hypsiconchy[†] Chamaeconchy[†] Brachystaphyly[*]	Leptorrhiny Hypsiconchy Hypsiconchy Brachystaphyly	Leptorrhiny[*] Chamaeconchy[*] Chamaeconchy[*] Brachystaphyly
Platyrrhiny	*L.* Chamaeconchy *R.* Chamaeconchy Brachystaphyly[*]	Chamaeconchy Chamaeconchy Leptostaphyly[†]	Chamaeconchy Chamaeconchy Leptostaphyly	Chamaeconchy Chamaeconchy Brachystaphyly[*]
Brachystaphyly	*L.* Chamaeconchy *R.* Chamaeconchy	Chamaeconchy[*] Chamaeconchy	Hypsiconchy Hypsiconchy	Hypsiconchy Hypsiconchy

L and *R* denote left and right orbit.

The comparatively high degree of association of platyrrhiny with chamaeconchy in both sexes is a marked feature in both races; so also is the very low correlation between the orbital indices and chamaecephaly and brachycephaly in the female of both races[‡].

Cephalic Indices and L, B and H.

Table XVII below shows the correlation of the cephalic indices, and the correlation of these indices with length, breadth and height, in English, French and Naqadas; also the spurious correlation where it exists. The coefficients have been calculated by the formulae given in K. Pearson's paper on Spurious Correlation*: to test the results obtained by the formulae, I worked out the coefficients in three cases directly from the actual numerical values of the characters in the same way as I calculated the coefficients shown in Table X, i.e. by summing the products of the actual pairs of values. The results compare as follows:—

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[*] Correlation very small, or almost insensible.

[†] Correlation insensible.

[‡] In the above Table I have corrected one or two slips in C. D. Fawcett's memoir; e.g., p. 460, she states that in the male Naqada chamaecephaly is associated with *brachystaphyline* characters and the little association in the female is with *leptostaphyline* characters. A glance at her Table on p. 455 shows that brachystaphyline and leptostaphyline have here got interchanged. p. 462 (*a*), brachycephaly as the table shows is associated with *chamaecranial* and not *hypsicranial* characters as inadvertently mis-read. Finally in (*b*) on the same page *platycranial* in line 2 of the paragraph must be interchanged with *stenocranial* in line 3.

Correlated pair	Coefficient by formulae	Coefficient by products
B/L and H/L ♂ (114 pairs)	·439 ± ·051	·436 ± ·051
B/L and H/L ♀ (108 pairs)	·391 ± ·055	·399 ± ·055
B/L and H ♂ (114 pairs)	·024 ± ·063	·021 ± ·063

The results obtained by the formulae and from the actual numerical values will be seen to agree very closely, and confirm C. D. Fawcett's conclusion† that it seems unnecessary in future to incur the labour of deducing the coefficients directly from the measurements.

Turning now to the Table, we observe that the spurious correlation between any of the pairs of characters is remarkably alike in both sexes and in all three series‡. In our series it is greater than the gross correlation in nine cases, practically equal in four, and in only one is it significantly less; we may therefore conclude, as C. D. Fawcett did from the Naqada and French data§, that "organic correlation between L, B and H often tends to reduce the result considerably below the value it would have if the lengths, breadths and heights had been selected from the records in random triplets, i.e. below the spurious correlation." Some further conclusions may be drawn:

(*a*) Dealing with the gross correlation, we see that in English, Altbayerisch, French and Naqadas, if an individual tends to brachycephaly, he will also tend to hypsicephaly.

(*b*) In our series, the correlation between the indices and the lengths which they do not involve is very low for both sexes, and this is true, though not quite to the same degree, of French and Naqadas.

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* *R. S. Proc.* Vol. 60, p. 493. Pearson's general formulae are easily adapted to the particular cases met with in the investigation.

† *Loc. cit.* p. 461. C. D. Fawcett's Table is clearly based on the French measurements and not on the Naqada as stated in the text.

‡ The only other calculation known to me, of spurious correlation in the skull, is that given by K. Pearson, *R. S. Proc.* Vol. 60, p. 495, for B/L and H/L in 100 Altbayerisch ♂ skulls, viz. ·4008; but this should be ·4347, which is more in accordance with the values in our Table. I may note the following further arithmetical corrections required in that paper: p. 495, read $r_{21} = {\cdot}19795$ for $r_{21} = {\cdot}1243$ and $\rho_0 = {\cdot}4347$ for ·4008; p. 496, read $\rho_0 = {\cdot}4613$ for $\rho_0 = {\cdot}4557$; p. 497, read $\rho_0 = {\cdot}4333$ for $\rho_0 = {\cdot}3904$.

§ *Loc. cit.* p. 461.

TABLE XVII.

Correlation of English Cranial Characters, and Comparison with other Races.

Pairs of characters	English Series					
	♂			♀		
	No.	Gross	Spurious	No.	Gross	Spurious
B/L and H/L	114	·439 ± ·051	·419 ± ·052	108	·391 ± ·055	·494 ± ·049
B/H and L/H	114	·580 ± ·042	·598 ± ·041	108	·581 ± ·043	·559 ± ·044
H/B and L/B	114	·478 ± ·049	·478 ± ·049	108	·522 ± ·047	·444 ± ·052
B/L and H	114	·024 ± ·063	—	108	− ·144 ± ·063	—
B/H and L	114	− ·048 ± ·063	—	108	− ·086 ± ·064	—
H/L and B	114	·072 ± ·063	—	108	− ·061 ± ·064	—
B/L and L	131	− ·547 ± ·041	− ·658 ± ·033	130	− ·541 ± ·042	− ·689 ± ·031
H/L and L	120	− ·477 ± ·047	− ·615 ± ·038	117	− ·475 ± ·048	− ·674 ± ·034
B/L and B	131	·682 ± ·032	·753 ± ·026	130	·599 ± ·038	·725 ± ·028
H/L and H	120	·728 ± ·029	·786 ± ·023	117	·596 ± ·040	·739 ± ·028
	French Series *					
B/L and H/L	860	·489 ± ·018	·464 ± ·019	340	·576 ± ·024	·477 ± ·028
B/H and L/H	860	·419 ± ·020	·527 ± ·017	340	·417 ± ·030	·541 ± ·026
H/B and L/B	860	·586 ± ·016	·508 ± ·018	340	·503 ± ·027	·482 ± ·028
B/L and H	860	− ·040 ± ·024	—	340	·068 ± ·036	—
B/H and L	860	− ·170 ± ·023	—	340	− ·143 ± ·036	—
H/L and B	860	·126 ± ·023	—	340	·211 ± ·035	—
B/L and L	860	− ·652 ± ·014	− ·686 ± ·013	340	− ·720 ± ·018	− ·705 ± ·018
H/L and L	860	− ·548 ± ·017	− ·677 ± ·013	340	− ·622 ± ·022	− ·677 ± ·020
B/L and B	860	·699 ± ·012	·727 ± ·011	340	·729 ± ·017	·714 ± ·018
H/L and H	860	·639 ± ·014	·736 ± ·011	340	·694 ± ·019	·736 ± ·017
	Naqada Series †					
B/L and H/L	130	·284 ± ·054	·432 ± ·048	166	·371 ± ·046	·438 ± ·043
B/H and L/H	131	·595 ± ·038	·603 ± ·037	163	·527 ± ·039	·552 ± ·037
H/B and L/B	131	·601 ± ·037	·459 ± ·046	163	·594 ± ·035	·508 ± ·040
B/L and H	130	− ·176 ± ·056	—	169	− ·111 ± ·053	—
B/H and L	131	− ·184 ± ·057	—	163	− ·115 ± ·053	—
H/L and B	131	− ·001 ± ·059	—	166	− ·003 ± ·054	—
B/L and L	130	− ·551 ± ·041	− ·694 ± ·031	169	− ·613 ± ·032	− ·673 ± ·028
H/L and L	131	− ·333 ± ·052	− ·623 ± ·036	166	− ·514 ± ·039	− ·651 ± ·031
B/L and B	130	·594 ± ·038	·720 ± ·028	169	·695 ± ·028	·740 ± ·024
H/L and H	131	·660 ± ·033	·782 ± ·023	166	·677 ± ·029	·759 ± ·023

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* Paris Catacomb Crania. The values were deduced from copies of Broca's MS. measurements sent by the kindness of M. Manouvrier to K. Pearson (C. D. Fawcett, *loc. cit.* p. 456).

† C. D. Fawcett, *loc. cit.* p. 456. A few slight slips in the arithmetic have been corrected, and the whole series of results now is in better accordance.

Finally, looking at the correlation between the indices and the absolute lengths which they involve, we observe that the following statements hold with regard to all three series, English, French and Naqadas.

(*c*) Dolichocephaly and chamaecephaly are associated with macrocranial characters.

(*d*) Brachycephaly is associated with platycranial characters.

(*e*) Hypsicephaly is associated with hypsicranial characters.

In (*c*), (*d*) and (*e*), the association is due entirely to the spurious correlation.

The technical descriptive terms are used above in an intra-racial sense. As usual, dolichocephalic, chamaecephalic, stenocephalic denote crania having their B/L, H/L and B/H indices below, brachycephalic, hypsicephalic, platycephalic denote crania having these indices above, the racial mean. Brachycranial, stenocranial and chamaecranial are used to denote individuals whose L, B and H are below, macrocranial, platycranial and hypsicranial denote individuals in which these measurements are above, the racial mean*. These terms cannot be used in an inter-racial sense until we have determined inter-racial means, that is, means of racial means, and little progress has as yet been made with such determinations. The only instances of which I am aware are to be found in *Biometrika*, Vol. II. p. 353, where Dr Alice Lee has found a scientific classification of cephalic index and nasal index in living races, based on the means of 51 races.

(12) *General Conclusions.*

I look upon this memoir as in the first place contributing new material in a reduced form to the collection of biometric data for man which is slowly being formed. Only when that collection is far more complete will it be possible to state general conclusions applying to the whole field of craniology. I venture to think that the chief aim of craniologists at present should be to table the means, standard deviations and correlations of further long series of skulls. When such tables have been formed for 40 or 50 long series we shall have far more light not only on intra-racial but on inter-racial problems.

Admitting that this is primarily a contribution to such a biometric description of mankind, we are still I think justified in drawing one or two general conclusions, partly with reference to the English cranium itself and partly with reference to its relation to other groups or series.

In the first place it will be noted that our material comes from a single centre, and it may be said not to be a fair sample of the English skull in general. The only reply that can be made to this is that whether judged by the biometric constants or by a careful appreciation of the material as a whole, the series appears to be homogeneous, and very different from German, French or other continental series with which we are acquainted. Further it is closely in accord with a second series from an entirely different burial spot on the opposite side of the city of London. We can therefore assert that in the 17th century there certainly did exist a remarkable type in the city of London, which is unlike any continental type with which we are familiar, and which is markedly different from what some authorities have supposed the English type to have been or at least now to be. It is quite true that isolated English skulls are to be found in museums which provide measurements not wholly in agreement with those of our two series*, but such skulls have often been selected as "fine" specimens, and the total material available in no way approaches the long series with which we are dealing. Until another long series or two of English skulls are measured, and are shown to differ sensibly from our two series, we may I think fairly assume that our results describe the English skull, or at least that of the typical citizen of London, in the only series that at present have reasonable weight. Indeed a proof that we are not dealing with anything *very* local and exceptional may be obtained by the comparison of the biometric constants of our Whitechapel series with those for the whole of Sir William Turner's Scottish series which I have calculated, correcting a few arithmetical slips in his Table XVI, and placed for comparison in Table XVIII below.

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* See Schmidt, *Anthropologische Methoden*, p. 296.

The most marked differences are here in the length, breadth and resulting cephalic index, as well as in the orbital measurements. The latter, however, differ so from observer to observer that they can hardly be used as a criterion. The general correspondence is apparent and considering the heterogeneity of the Scottish series, remarkable.

When we turn to our series we see that it is markedly differentiated not only from existing continental types but from earlier racial types in Britain by its extreme length. This extreme length seems closely associated with protuberance of the occiput or even bathrocephalic abnormality. In the first gathering of the Whitechapel crania, which covered Nos. 7037—7127 of our Tables there was a distinct attempt to collect skulls of anatomical interest†, but afterwards the whole material was brought to University College. Of course if any large number of the crania had been stolen between the two removals, this would have emphasised the proportion of remarkable skulls in the series. But we do not believe that any sensible effect was produced in this way; and we hold this for the simple reason that in the crania from Moorfields, there is at least an equally large proportion of abnormal or remarkable crania; the latter collection was made on one occasion and embraced we believe the complete series of excavated skulls. Indeed bathrocephaly and protuberance of occiput are, if anything, more marked in the Moorfields than in the Whitechapel crania*. The great average length, the comparative narrowness and the resulting degree of dolichocephaly, are of course not the only distinguishing marks of the Whitechapel crania, but they are those which strike the most casual observer. They lead us at once to ask: Where can we find anything which in the least corresponds to these English characters? The answer appears to be only in the Long Barrow crania of this and other

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* Modern English skulls essentially of the present type are indeed to be found in museums, for example the skull No. 565 of the Oxford Collection, which the cataloguer finds "remarkable for its length." Did he compare it with any collection of English crania, or only with those of the crania of other races in the museum? Professor Pearson is in part responsible for the inferences drawn in this concluding section.

† This fact will explain the extension of the "Remarks" peculiar to these numbers in the Tables of measurements.

TABLE XVIII.

Comparison of Scottish and Whitechapel Skulls.

Character	♂						♀					
	Scottish			Whitechapel			Scottish			Whitechapel		
	Mean	S. D.	C. of V.	Mean	S. D.	C. of V.	Mean	S. D.	C. of V.	Mean	S. D.	C. of V.
C	1496	—	—	1477	—	—	1323	—	—	1300	—	—
L	186·8	7·42	3·97	189·1	6·27	3·31	178·9	7·15	4·00	180·4	6·22	3·45
B	144·3	5·94	4·11	140·7	5·28	3·75	137·8	5·11	3·71	134·7	4·77	3·54
H	132·4	6·10	4·60	132·0	5·56	4·21	126·2	5·02	3·98	124·6	4·93	3·96
LB ...	101·4	—	—	101·6	—	—	95·3	—	—	95·3	—	—
U	531·2	—	—	524·2	—	—	506·7	—	—	503·8	—	—
$G'H$ ...	71·7	—	—	70·2	—	—	66·9	—	—	65·9	—	—
J	132·4	—	—	130·0	—	—	121·6	—	—	120·3	—	—
NH ...	52·4	3·21	6·12	51·2	2·60	5·08	49·9	2·93	5·86	48·7	2·70	5·55
NB ...	23·2	1·78	7·69	24·3	2·16	8·89	22·0	1·85	8·41	23·2	1·64	7·06
O_1	39·1†	1·86	4·76	43·0‡	L 1·81 R 2·02	4·20 4·69	37·4†	1·61	4·31	41·1‡	L 1·45 R 1·64	3·53 4·00
O_2	34·1†	2·58	7·57	33·4‡	L 1·88 R 2·22	5·61 6·65	33·4†	2·58	7·71	33·7‡	L 1·45 R 1·51	4·31 4·47
GL ...	96·1	—	—	95·9	—	—	91·2	—	—	90·4	—	—
$100GL/LB$	94·9	—	—	94·4	—	—	94·9	—	—	94·8	—	—
$100B/L$ ...	77·3	—	—	74·3	—	—	77·1	—	—	74·7	—	—
$100H/L$ ...	70·9	—	—	70·0	—	—	70·5	—	—	69·1	—	—
$100NB/NH$	44·5	3·80	8·54§	47·6	4·58	9·64	44·1	4·64	10·53§	47·8	3·90	8·16
$100O_2/O_1$ ...	87·3	5·49	6·29§	77·8‡	L 3·78 R 4·66	4·86 6·00	89·4	6·85	7·66§	82·1‡	L 4·23 R 4·33	5·18 5·25
$100G'H/J$..	54·4	—	—	53·8	—	—	55·1	—	—	54·8	—	—

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[*] Special prominence will be given to these features in the plates to the memoir on the Moorfields crania.

[†] Apparently only one orbit was measured, and which not stated; O_1 was measured from the dacryon, and hence is not properly comparable with our O_1.

[‡] Average of our L and R.

[§] With reference to these indexes, Sir William Turner writes, p. 603: "*Orbital Index*....My obser-" vations on the orbital index in the skulls of numerous races have satisfied me that it presents a great" range of variation in the same race, and that it possesses only a secondary value as a race character. "*Nasal Index.* The relation between the height of the nose, measured from the nasion to the lower" border of the apertura pyriformis, and the greatest width of that aperture, constitutes one of the most" important anthropological characters of the face."

It will be observed, however, that the variability, as measured by the coefficient of variation, of the nasal index is much greater, both in males and females, than that of the orbital index, and this is true of the Whitechapel and Naqada series as well as of the Scottish.

countries. They agree with nothing else on the continent with which we are acquainted. Our crania do not accord with Anglo-Saxon, with Romano-British or with Round Barrow British, but are in general appearance and biometric constants remarkably close to the Long Barrow British. I have endeavoured to indicate this in the accompanying Table:

TABLE XIX.

Comparison of Means of Modern English and Long Barrow Crania.

Character	Whitechapel Crania 43 to 137 ♂ s	Moorfields Crania 19 to 46 ♂ s	Long Barrow Crania, Oxford, measured by E. Schuster* 11 to 17 ♂ s	Long Barrow Crania, Cambridge, measured by A. Macalister† 37 to 54 ♂ s	Reihengräber Schädel‡ 6 to 16 ♂ s	Swedish Crania, stone age, Retzius‡ 13 to 25 ♂ s
C ...	1477	1473	—	—	1455	1498
L ...	189	189	190	196	193	187·5
B ...	141	143	140	140	142	142
B' ...	98	98	99	98	98	98
H ...	132	130	135	137	140·5	138
U ...	524	527	533	538	534	527
S ...	377	379	384	—	385	379
Q ...	308	305	320	314	—	324
$G'H$ ...	70	68	70	—	69	69·5
J ...	130	129§	134	—	132	132
$100G'H/J$...	54	52‖	52	—	52	53
$100B/L$ ...	74	75	74	71	74	76
$100H/L$ ...	70	68	71	70	73	74

An examination of these characters seems to warrant the statement, which is amply borne out by the method of 'appreciation,' that the crania of Londoners of not more than 200 to 300 years ago indicate that a very large proportion of the inhabitants of London at that time were of a type which can only be described as approaching that of Long Barrow men. If they were so then, the type is certainly not extinct now, and we may even venture to describe the ancestor of the genuine cockney as a Long Barrow man. Whether the Long Barrow Man has remained a denizen of London through all the invasions to which the country has been subject, or whether a process of selection has gone on, the London environment being suited only to the Long Barrow type, we cannot yet say, but when long series of modern English skulls from other places are dealt with, we shall no doubt see our way further. Meanwhile the only general conclusion which we can reach

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[*] Unpublished measurements for which we have heartily to thank Mr E. Schuster.

[†] We must cordially thank Professor A. Macalister for sending us copies of his measurements on these crania. They originally belonged to Thurnam (see his paper: *On the two Principal Forms of Ancient British and Gaulish Skulls*, 1865; Table I), but Thurnam's measurements are doubtful and his averages are incorrect.

[‡] Deduced by K. Pearson from measurements given in the German Anthropological Catalogue, and in G. Retzius, *Crania Suecica Antiqua*, Tafel I., respectively.

[§] Mean of 7 crania only. [‖] Mean of 6 crania only.

is the simple but startling one, that the London City crania—from Whitechapel to Moorfields—are far more closely allied to the Long Barrow type than to any other. We do not see how to avoid this conclusion, it is hardly needful to say that, if verified, its importance from both the craniological and historical standpoint can hardly be exaggerated. It would mean that at any rate a section—probably a large section—of the English population are not Anglo-Saxon, nor Scandinavian, nor even Celtic, but belong to a still earlier race.

Regarding our present material in conjunction with the other series dealt with for comparative purposes, we must draw very similar conclusions to those already propounded in C. D. Fawcett's memoir, i.e.:

The correlations between cranial characters are generally low and vary considerably from race to race. All generalisation from individual series—or, as it often happens, from individual skulls—to wide craniological laws seems to be idle. The present great need of craniology is the accumulation of intra-racial biometric constants with a view to the ultimate calculation of inter-racial means, standard deviations and correlations. These will provide the only possible basis for a correct theory of race in man, as well as for a really scientific craniological terminology.

Appendix of Tables of Measurements.

The measurements are tabled in nearly the same manner as in the case of the Naqada crania. The notation used is identical:

Thus cr. = *cranium*, i.e. skull + mandible; cal. = *calvarium* = skull − mandible; f. stands for face. Thus cal. − f. = calvarium − face bones; dome = the roof of the skull only (*Schädeldach*). These terms are in accordance with those used in C. D. Fawcett's memoir, and are close to the terms adopted in Germany. Probably the English use of cranium for what is above called calvarium, and of calvarium for "dome," would have been better. But it did not seem desirable to change from the notation already adopted in *Biometrika*.

In calculating the constants involving length of skull, Nos 186, 7042 and 7059 were excluded on account of their extreme bathrocephaly.

In the age statements, which are of course only appreciations, *child* = an individual less than 15 years, *adolesc.* 15—20, *y. ad.* 20—30, *ad.* 30—50, and *old* above 50.

During the past winter Professors Thane and Pearson went through the whole series of skulls again and the former not only again considered questions of sex and probable age, but supplied the anatomical notes which are embodied in the accompanying "Remarks" on the crania. I have thus not only to thank him for allowing me to work on his splendid material, but also for the time he has spent on a lengthy anatomical examination of the whole series. Added to these matters all biometric workers at University College have had experience of his ready aid and advice at many stages of their investigations.

Addenda.

The following capacities omitted by oversight should be entered in the Tables: W. 7037, C = 1320 and W. 7041, C = 1650.

The Editors have to acknowledge a grant from the Publication Fund of the Royal Society towards the printing of the 50 plates accompanying this paper. The blocks for these were paid for out of a grant from the Drapers' Company's Donation to the Department of Applied Mathematics in University College, London, as already stated on p. 215.

MEASUREMENTS

TABLE I.

Face						Remarks
J	*NH*	*NB*	O_1		O_2	
			L	*R*	*L*	
—	50	—	43	—	33	. r. side of face defective
—	56·5	25·5	44	45	33·5	. cranial wall large defects
127	49	23	41·5	40·5	30·5	. small defects vault and base
—	52	23	42	40·5	33·5	. base very imperfect
—	—	—	—	—	—	f. old? defects in wall
—	47·5	21	42	42	34·5	. ad. left side very defective, *os pentagonale*
—	50	21	44	45·5	33·5	.
—	—	—	—	—	—	f. ad. defect in vault
—	47·5	20	36	35·5	34	. ad. zygom. arches defective. infantile type of
						head. somewhat plagiocephalic. post coronal
						striction ; r. occipital flattening
132	48·5	22·5	40·5	41	30·5	l.
—	—	—	—	—	—	f. ad. defective ethmoidal region
—	—	—	—	—	—	f. ad. defective base, numerous worm. ossicles
						mbdoid suture; ossicle 18 × 8 mm. in r. coronal
—	—	—	—	—	—	f. old? [suture
—	—	—	—	—	—	f. sen? fracture across base. slight projection
						basi-occipital [poral region
120	51	23	42	42·5	35·5	. post mortem depression and defect in l. tem-
—	52	23	40	—	32·5	l. right side of face, l. zygom. arch defective.
						mian bone on hinder part sagit. suture
126	49	22·5	40	41	33	l.
—	—	—	—	—	—	f. y. ad. two wormian bones, together 37 × 26 mm.,
						inder part of sagit. sut. projecting into r. parie-
						bone
—	48·5	—	—	41	—	y. ad. very imperfect
—	—	—	—	—	—	f. y. ad. large occipital defect. metopic; slight
						coronal constriction; bilateral frontal process of
						amous temporal; slight depression of obelion
—	—	—	—	44	—	f. + r. orbit. ad.
—	—	—	—	—	—	f. ad. with defects r. side. [depression obelion
—	—	—	—	—	—	f. ad. slight defect anteriorly. metopic; slight
—	52·5	—	—	44·5	—	. l. side of face defective. slightly bathrocephalic
—	52·5	—	—	45	—	l. large defect l. side
—	—	—	—	—	—	f. ad. slight bathrocephaly
121	46	25	39	40	33	d. faint depression obelion
—	—	—	—	—	—	f. ad. considerable defect in forepart of base
—	—	—	—	—	—	f. y. ad. slight *torus occipitalis*
—	—	—	—	—	—	ad. wormian bones between occipital, parietal
—	—	—	—	—	—	f. old. defective in r. parietal [and mastoid
—	48·5	25·5	—	44	—	y. ad. l. side of face defective
—	—	—	—	—	—	f. old. defects in base and l. temporal
—	—	—	—	—	—	ad. with fracture
—	—	—	—	—	—	f. ad. large occipital defect [to r. temporal
—	—	—	—	—	—	f. ad. with l. parietal defect. frontal process
—	—	—	—	43	—	f. + r. orbit. ad.
—	—	—	—	—	—	f. ad. defective r. temporal and ethmoidal regions
—	—	—	—	—	—	f. old. defective base [bathrocephaly
—	—	—	—	—	—	f. ad. metopic; post coronal depression; slight
117	47	21·5	40·5	39	34	d. r. parietal and l. occipital defects; slight
						coronal depression [part sagital suture
—	—	—	—	—	—	f. y. ad. metopic; wormian bones in hinder
—	—	—	—	—	—	f. ad. depression of obelion
135	53	24	44·5	45·5	33·5	l. [dylar eminences on basi-occipital bilateral
—	49·5	23·5	40·5	41	33·5	y. ad. l. temporal bone wanting; small precon-
—	—	—	—	—	—	f. ad. defects in base, slight post coronal de-
—	—	—	—	—	—	f. y. ad. [pression
—	46	22	39	—	32·5	l. defects in base and r. malar region
—	—	—	—	—	—	f. ad.
—	47	23·5	42	—	35	l. defect in r. malar region
—	51·5	24·5	47	47	35·5	y. ad. l. zygomatic defect
—	—	—	—	—	—	f. ad. sphenoid and temporal defective l. side.
						ked bathrocephaly; numerous wormian bones
						ambdoid suture, slight *torus occipitalis*
—	—	—	—	—	—	f. ad. considerable defects

MEASUREMENTS OF SEVENTEENTH CENTURY ENGLISH CRANIA.

TABLE I.

			Lengths								Circumferences			Face									Palate		Indices											Angles						Remarks
Series No.	Sex	*C*	*F*	*L′*	*L*	*B*	*B′*	*H*	*OH*	*LB*	*U*	*S*	*Q*	*GH*	*GB*	*J*	*NH*	*NB*	O_1 *L*	O_1 *R*	O_2 *L*	O_2 *R*	G_1	G_2	*B/L′*	*H/L′*	*B/L*	*H/L*	*B/H*	*G′H/GB*	*NB/NH*	O_2/O_1 *L*	O_2/O_1 *R*	G_2/G_1	*GL*	*N*∠	*A*∠	*B*∠	θ_2	θ_1	*P*∠	
1	♂	1615	186	188	188	146	99	136	120	105	525	381	325	—	—	—	50	—	43	—	33	—	51	35	77·7	72·3	77·7	72·3	107·4	—	—	76·7	—	68·6	96	—	—	—	—	—	—	cal. ad. r. side of face defective
2	♂	—	194	—	196	141	103	139	112 *h*	112	—	376	—	75	—	—	56·5	25·5	44	45	33·5	34	52	45	—	—	71·9	70·9	101·4	—	45·1	76·1	75·6	86·5	102	62°·5	77°·5	40°	—	—	—	cal. ad. cranial wall large defects
3	♂?		187	187	187	141	97		114	—	525	374	311	69	92	127	49	23	41·5	40·5	30·5	32		35·5	75·4	—	75·4			75	46·9	73·5	79						—	—	91°	cal. ad. small defects vault and base
4	♂		197		198	139	95				543	400		72			52	23	42	40·5	33·5	33·5	43	35		—	70·2				44·2	79·8	82·7	81·4					—		—	cal. ad. base very imperfect
5	♂		185		187	140	97	127	111 *h*	100	522	370	296						—	—		—	—	—			74·9	67·9	110·2		—	—	—	—	—	—	—	—	—	—	—	cal. – f. old? defects in wall
6	♀?		180		181		88	125	110 *h*	97	—	361	—	66·5	89	—	47·5	21	42	42	34·5	33·5	45·5	34·5	—	—	—	69·1	—	74·7	44·2	82·1	79·8	75·8	92	65°	73°·5	41°·5	—	—	—	cal. y. ad. left side very defective, *os pentagonale*
7	♂	1435	188	191	191	140	99	140	114	108	522	370	302	70·5	88		50	21	44	45·5	33·5	33·5	44·5	32·5	73·3	73·3	73·3	73·3	100	80·1	42	76·1	73·6	73	94·5	59°·5	80°·5	40	8°·5	31°·5	89	cal. ad.
9	♂		198		200	136	97	134	117 *h*	104	545	395	315							—		–	—	–			68	67	101·5	—		–	–	–	–	–	–	–	—	—	—	cal. – f. ad. defect in vault
10	♂	1280	186	184	184	127	84	122	109	95	505	381	287	62·5	76		47·5	20	36	35·5	34	33·5	43	33·5	69	66·3	69	66·3	104	82·2	42·1	94·4	94·4	77·9	89	65	75°·5	39°·5	14°·5	25	90°	cal. y. ad. zygom. arches defective, infantile type of forehead, somewhat plagiocephalic, post coronal constriction; r. occipital flattening
11	♂	1595	187	187	187	145	102	140	120	104	526	381	322	67?	88	132	48·5	22·5	40·5	41	30·5	29·5	51	32	77·5	74·9	77·5	74·9	103·6	76·1	46·4	75·3	71·9	62·7	94·5	62°·5	78°	39°·5	11°	28°·5	89°	cal. ad.
12	[illegible]	1595	193		198	141	103	138	119 *h*	113	537	385	315							—					–	—	71·2	69·7	102·1				–									cal. f. ad. defective ethmoidal region
13	♂		184		188	142	102	128	112 *h*	102	525	364	306	—					—	—	—	—	—	—	—	—	75·5	68·1	111	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. defective base, numerous worm. ossicles in lambdoid suture; ossicle 18 × 8 mm. in r. coronal [suture
14	♀	1220	172	—	173	130	90	129	109 *h*	93	484	356	291	—	—	—	—	—	—	—	—	—	—	—	—	—	75·1	74·6	100·8	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. old?
15	♀	1235	168	—	168	136	94	127	116 *h*	96	485	343	309	—	—	—	—	—	—	—	—	—	—	—	—	—	80·9	75·6	107·1	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. sen? fracture across base slight projection on basi occipital
16	[illegible]	1270	186	187	187	127	93	122	107	95	509	372	283	71·5	84	129	51	23	42	42·5	35·5	34·5	45	34	67·9	65·2	67·9	65·2	104	85·1	45·1	84·5	81·2	75·6	90·5	64	71	45	15	30	86	cal. ad. post mortem depression and defect in l. tem [poral region
17	♂	1515	[illegible]	189	190	131	89	132	116	102	513	385	303	72			52	23	40	—	32·5		46	37·5	69·3	69·8	68·9	69·5	99·2		44·2	81·2		81·5	95	63°·5	74	42°·5	15	27°·5	89	cal. ad. right side of face, l. zygom. arch defective. wormian bone on hinder part sagit. suture
18	[illegible]	1345	175	174	175	139	97	125	108	97	504	352	293	63	91	126	49	22·5	40	41	33	32·5	47·5	32	79·9	71·8	79·4	71·4	111·2	69·2	45·9	82·5	79·3	67·4	93	67°	74°	39°	11°	28°	85°	cal. ad.
19	[illegible]	1160	175		175	130	92	121	111 *h*	91	496	365	295				—	—	–	—	—	—	—	—	—	—	74·3	69·1	107·4	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. y. ad. two wormian bones, together 37 × 26 mm., in hinder part of sagit. sut. projecting into r. parietal bone
20	♀	—	177	177	177	—	90	119	106	95	—	—	286	66	—	—	48·5	—	—	41	—	32	45	—	—	67·2	—	67·2		—	–		78		92	67°	72°	41°	15°	26°	87°	cal. y. ad. very imperfect
21	♂?		—			130	101	125	103 *h*	95			293							—	–			–					105·8		– –					–			– –	—	—	cal. f. y. ad. large occipital defect, metopic; slight post coronal constriction; bilateral frontal process of squamous temporal; slight depression of obelion
22	♂?	1670	189	—	190	144	102	135	119 *h*	103	533	380	321	—	—	—	—	—	—	44	—	34·5			—	—	75·8	71	106·7				78·4									cal. f. + r. orbit. ad.
23	[illegible]		178		179		91	138	118 *h*	105	485	365	301							—	—				—		—	77·1						—								cal – f. ad. with defects r. side.
24	[illegible]	1230	170		169	134	97	124	110 *h*	93	487	340	295														79·3	73·4	108·1		—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. slight defect anteriorly, metopic; slight [depression obelion
25	[illegible]	1470	187	189	190	142	101	127	109	103	525	368	298	73·5	—	—	52·5	—	—	44·5	—	34·5	—		75·1	67·2	74·7	66·8	111·8	—		—	77·5	–	98	65°	72	43	13	30	85	cal. ad. l. side of face defective. slightly bathrocephalic
26	[illegible]		190	189	190	140		134	118	102	527	388	309				52·5			45	—	30			74·1	70·9	73·7	70·5	104·5				66·7		—				—			cal. ad. large defect l. side
27	[illegible]	1240	176		177	138	91	128	113 *h*	91	495	360	304												—	—	78	72·3	107·9		—		–	–		—		—	—		–	cal f. ad. slight bathrocephaly
28	[illegible]	1315	186	186	186	140	97	121	107	93	521	372	299	63·5	88	121	46	25	39	40	33	33·5	45·5	32	75·3	65	75·3	65	115·7	72·2	54·3	84·6	83·7	70·3	93	70	70	40	13	27	83	cal. old. faint depression obelion
29	[illegible]		188		190	131		130	115 *h*	103	513	373	293														68·9	68·4	100·8			—	–	—	—	—	—	—	—	—	—	cal. – f. ad. considerable defect in forepart of base
30	[illegible]	1325	176		176	138	96	125	108 *h*	93	505	361	299	—	—	—	—	—	—	—	—	—	—	—	—	—	78·4	71	110·4	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. y. ad. slight *torus occipitalis*
31	[illegible]		197		198	144	98	– –	114 *h*	—	548	390	310	—	—	—	—	—	—	—	—	—	—	—	– –		72·7					—	—	—	—	—	—	—	—	—	—	dome. ad. wormian bones between occipital, parietal [and mastoid
32	[illegible]		183		184	140	94	133	119 *h*	92	518	391	322	—	—	—	—	—	—	—	—	—	—	—	—	—	76·1	72·3	105·3	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. old. defective in r. parietal
33	[illegible]	1405	185	186	186	138	[illegible]	135	113	105	520	369	305	67	—	—	48·5	25·5	—	44	—	31·5	52		74·2	72·6	74·2	72·6	102·2		52·6		71·6		102	68°·5	73°·5	38	10°·5	27°·5	84	cal. y. ad. l side of face defective
34	[illegible]		178		177	131	93	124	[illegible]	94	495	362	293	–											—	–	74·6	70·1	106·5						–				—		–	cal f. old. defects in base and l. temporal
35	[illegible]		187		[illegible]	136	[illegible]		100 *h*		524	370	—												.	–	73·2															dome ad. with fracture
36	[illegible]		181		181	127	88		115 *h*		497		280												.	—	70·2					–	– –		—							cal. – f. ad. large occipital defect
37	[illegible]		182		184			126	110 *h*	101	503	304	291	—	—	—	—	—	—	—	—	—	—	—	—	—	—	68·5	—	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. with l. parietal defect. frontal process [to r. temporal
38	[illegible]	1305	174	176	176	147	95	126	113	98	509	360	309	—	—	—	—	—	—	43	—	35	—	—	83·5	71·6	83·5	71·6	116·7				81·4		—	—	—	—	—	—	—	cal. – f. + r. orbit. ad.
39	[illegible]		179		181	137	93	132	113 *h*	100	505	369	308														75·7	72·9	103·8		—				– –							cal. – f. ad. defective r. temporal and ethmoidal regions
40	[illegible]		169		169	130	84	120	107 *h*		476		285														76·9	71	108·3						–							cal. – f. old. defective base [bathrocephaly
41	[illegible]	1415	183		185	139	97	128	109 *h*	97	523	369	303												—	—	75·1	69·2	108·6	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. metopic; post coronal depression; slight
42	[illegible]		171	171	171	135	85	116	102	91	490	—	275	63	83	117	47	21·5	40·5	39	34	34·5	40	33·5	78·9	67·8	78·9	67·8	116·4	75·9	45·7	83·9	88·5	83·7	84	63°	75°	42°	14°	28	89	cal. ad. r. parietal and l. occipital defects, slight post coronal depression
43	[illegible]	1400	182		181	139	92	123	115 *h*	89	510	387	303	—						—							76·8	68	113	–		—	–		– –			–	—	–		cal. – f. y. ad. metopic; wormian bones in hinder [part sagital suture
44	[illegible]	1160	177		177	131	95	118	102 *h*	94	493	342	281	–											—	—	74	66·7	111	–										– –		cal. f. ad. depression of obelion
45	[illegible]	1405	186	186	190	141	100	136	114	100	521	382	307	68	89	135	53	24	44·5	45·5	33·5	33·5		40?	74·6	72	74·2	71·6	103·7	76·4	45·3	75·3	73·6	–	99	66°·5	73	40°·5	8	32°·5	81	cal. ad.
46	[illegible]		182		184	137	92	131	112 *h*	99	505	362		65·5	89		49·5	23·5	40·5	41	33·5	34	46	34		—	74·5	71·2	104·6	73·6	47·5	82·7	82·9	73·9	95	67	73°·5	39°·5				cal. y. ad. l. temporal bone wanting; small precon- [dylar eminences on basi-occipital bilateral
47	[illegible]	1455	182		186	141	91	126	112 *h*	98	512	370	307						–				–				75·8	67·7	111·8			–		–		–						cal. f. ad. defects in base, slight post coronal de- [pression
49	[illegible]	1275	173		172	134	91	122	106 *h*	92	491	359	287								–						77·9	70·9	110		. .											cal. – f. y. ad.
50	[illegible]	1388	177	175	175	135	93		112		499	371	302	60	83	—	46	22	39	—	32·5	32	43	36·5	77·1	—	77·1	—	—	72·3	47·8	83·3	—	84·9	—	—	—	—	—	—	88°	cal. ad. defects in base and r. malar region
51	♂?	1405	191	—	192	136	101	126	115 *h*	101	528	385	312	—	—		—	—	—	—	—	—	—	—	—	—	70·8	65·6	108	—		–		–		–	–	–				cal. f. ad.
52	♀	1460	187	186	188	138	95	139	117	104	516	372	307	71			47	23·5	42		35	35	48	36	74·2	74·7	73·4	73·9	99·3		50	83·3	—	75	95	62°·5	76°	41°·5	10°	31°·5	86°	cal. ad. defect in r. malar region
53	[illegible]	1315	187	187	188	132	100	133	114	107	513	369	300	70·5	—	—	51·5	24·5	47	47	35·5	35·5	51·5	40	70·6	71·1	70·2	70·7	99·2	—	47·6	75·5	75·5	77·7	102	66°·5	74°·5	39°	10°·5	28°·5	85°	cal. y. ad. l zygomatic defect
54	[illegible]		186		186	140	92	139	117 *h*	99	525	388	—	—	—	—	—	—	—	—	—	—	—	—	—	–	75·3	74·7	100·7					–				–	—	—	—	cal. – f. ad. sphenoid and temporal defective l. side. marked bathrocephaly; numerous wormian bones in lambdoid suture, slight *torus occipitalis*
55	♀	—	178	—	180	132	95	129	113 *h*	97	496	361	291	—	—	—	—	—	—	—	—	—	—	—	—	—	73·3	71·7	102·3	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. considerable defects

Nos. 8 and 48 not seen.

MEASUREMENTS OF TABLE II.

Face						Remarks
			O_1			
J	*NH*	*NB*	*L*	*R*	*L*	
—	—	—	—	—	—	f. ad. hinder part defective. infantile forehead
—	—	—	—	—	—	f. ad. small r. parietal defect. ossicle of aste- ı, bilateral. left mandibular articulation imper- ly developed
119	46	23·5	40·5	40·5	30·5	y. ad. both zygomatic arches defective. depres- ı r. frontal. slight precondylar eminences on i-occipital, bilateral
—	—	—	—	—	—	ad.
—	48	22·5	—	42	32·5	l. l. malar defect.
—	52	22·5	41	41	33·5	l. left zygomat. arch and r. maxilla defective
—	56	25	—	46	—	old. l. malar defect. [arch metopic
—	46	23	42·5	41·5	33·5	y. ad. defect in r. parietal and l. zygom.
—	—	—	—	—	—	f. ad. defect centre of base. small occipital ıs. traces of ossicles in lambdoid suture. de- ssion in obelion
118	—	—	—	41·5	—	f. + r. malar bone. ad. ossicle to left of λ.
—	—	—	—	—	—	f. y. ad. small defect r. occipital. slight de-
—	—	—	—	—	—	f. ad. fractured base [pression of obelion
128	50	25·5	41·5	42·5	31·5	old. slight bathrocephaly
—	—	—	—	—	—	f. old. defect centre of base
—	—	—	—	—	—	f. old. ethmoidal defect. Projection 3 × 3 mm. at on into foramen (? rudimentary *condylus tertius*)
—	57	26	41	40	32·5	senile. both zygom. arches and centre of base ctive. metopic suture nearly closed. bilateral tal process of squamous temporal. small *torus* *pitalis.* traces of ossicles in lambdoid suture
—	—	—	—	—	—	. y. ad. defects in base, ethmoidal and l. tem- l. metopic. extensive flattening of obelion. small teral precondylar eminences on basi-occipital
—	—	—	—	—	—	f. y. ad. ossicles in hinder part sagit. suture
—	52·5	28	41·5	41	33	. defective l. zygom., l. parietal and occipito- poral. negroid appearance ?
—	49	22·5	—	42	—	. defect frontal and l. side face. irregular line mbdoid suture
—	51	23·5	42	—	34	. defect r. frontal and malar
—	50	25	—	41	—	old. defect l. side face
—	—	—	—	—	—	. old. sagit. sut. completely obliterated
—	44	21	39	40	30·5	. ad. right temporal defect. wormians in lamb-
—	50·5	25	42	42	33	. ad. l. zygoma defective [doid suture
—	—	—	—	—	—	. y. ad. r. ossicle of pterion
—	—	—	—	—	—	. y. ad. slight ethmoidal defect, r. ossicle of
124	52	23·5	41	40·5	32·5	. [pterion
117	50	20	41	42	34·5	. projection 8 mm. long from hinder margin ternal pterygoid plate on r. side
124	51·5	21	41	39	36	ad. projection 4 mm. long from hinder margin ternal pterygoid plate on r. side. metopic suture sting for 23 mm. at upper end
—	—	—	—	—	—	ad. frontal defect
—	52·5	24	—	—	—	r. occipito-temporal defect, face defective on sides. heavy brow ridges. slight bathrocephaly
—	—	—	—	—	—	ad. slight ethmoidal defect [fective
—	46·5	24	—	37·5	32·5	ld. large occipital defect, both zygomata de-
127	52·5	24	40·5	41·5	34	both zygomata defective
—	—	—	—	—	—	ad. small occipital defect
—	—	—	—	—	—	ad. base very defective
—	—	—	—	—	—	ad. centre of base defective
—	—	—	—	—	—	ad. metopic suture persisting for 35 mm. at r end, traces of trans-occipital suture for about m. ossicle in fore part l. squamous suture
—	—	—	—	—	—	ad. slight ethmoidal defect. post parietal ning and slight depression of obelion. traces of -occipital suture for 45 mm. on l. side
—	49·5	24·5	40·5	40·5	35	d. large occipital and l. temporal defect, three es in lambdoid suture, largest 20 × 10 mm.
131	50	26	41·5	40·5	32·5	right temporal defect

TABLE II.

MEASUREMENTS OF SEVENTEENTH CENTURY ENGLISH CRANIA.

Series No.	Sex	C	LENGTHS								CIRCUMFERENCES			FACE									PALATE		INDICES											ANGLES						Remarks
			F	L′	L	B	B′	H	OH	LB	U	S	Q	G′H	GB	J	NH	NB	O_1 L	O_1 R	O_2 L	O_2 R	G_1'	G_2	B/L′	H/L′	B/L	H/L	B/H	G′H/GB	NB/NH	O_2/O_1 L	O_2/O_1 R	G_2/G_1	GL	N∠	A∠	B∠	α	β	P∠	
56	♀				-	139	95	127	114 h	92		-	314						—										109·4		—	—	—	—	—	—	—	—				cal. f. ad. hinder part defective. infantile forehead
57	♀	1375	180		180	138	95	130	114 h	98	508	364	305						-								76·7	72·2	106·1						-							cal. f. ad. small r. parietal defect. ossicle of asterion, bilateral. left mandibular articulation imperfectly developed
58	♂ ?	1305	186	186	186	134	92	129	117	94	511	380	302	65	82	119	46	23·5	40·5	40·5	30·5	30·5	48·5	37	72	69·3	72	69·3	103·8	79·3	51·1	75·3	75·3	76·3	95	71	69	40	15	25	84	cal. y. ad. both zygomatic arches defective. depression r. frontal. slight precondylar eminences on basi-occipital, bilateral
59	♀		175		177	128	86		106 h		491	352	280								—			-	-		72·3	-		-											—	dome ad.
60	♂	1300	187	188	188	140	101	127	112	97	524	373	300		87		48	22·5		42	32·5	32·5	44	—	74·5	67·5	74·5	67·5	110·2		46·9		77·4		87·5							cal. ad. l. malar defect.
61		1410	177	180	180	135	[illegible]	130	115	98	505	362	303	71			52	22·5	41	41	33·5	33	-		75	72·2	75	72·2	103·8	-	43·3	81·7	80·5		86	58·5	77	44·5	16	28·5	93	cal. ad. left zygomat. arch and r. maxilla defective
62		1585	191	190	191	141	[illegible]	137	110	103	[illegible]	385	319	77·5	88		56	25		46		37·5	50	34	74·2	72·1	73·8	71·7	102·9	88·1	44·6		81·5	68	[illegible]	65	70	45	15	30	85	cal. old. l. malar defect.
63	♀		181	180	181	137	100	124	107	97	511	362	297	65	86		46	23	42·5	41·5	33·5	33·5	46		70·1	68·9	75·7	68·5	110·5	75·6	50	78·8	80·7		92	66	74	40	11	29	85	cal. y. ad. defect in r. parietal and l. zygom. arch. metopic
65	♂		197		199	143	100		121 h		540	402	324	-					—		—	-	—				71·9		—		—										-	cal. f. ad. defect centre of base. small occipital torus. traces of ossicles in lambdoid suture. depression in obelion
66	♂	1290	176	174	175	132	101	121	107	93	500	356	292	—		118				41·5		36			75·9	69·5	75·4	69·1	109				86·7			-					—	cal. f. + r. malar bone. ad. ossicle to left of λ.
67	♂	1425	181		182	138	94	124	111 h	94	509	358	301								—						75·8	68·1	111·2												-	cal. f. y. ad. small defect r. occipital. slight depression of obelion
68	♀	1170	167		167	136	89	126	108 h	92	481	350	292														81·4	75·4	108												—	cal. f. ad. fractured base
69	♂	1470	185	188	188	134	90	135	117	101	513	381	303	66	91	128	50	25·5	41·5	42·5	31·5	31·5	49	40	71·3	71·8	71·3	71·8	99·3	72·5	51	75·9	74·1	81·6	99	69	72·5	38·5	9·5	29	82	cal. old. slight bathrocephaly
70	♀	-	188		188	143	90		113 h		533		307								—	—	-		-	—	76·1		—							—					-	cal. f. old. defect centre of base
71	♀	1160	178		179	135	[illegible]	114	99 h	91	500	349	275								-	—			-		75·4	63·7	118·5						—						—	cal. f. old. ethmoidal defect. Projection 5 × 3 mm. at basion into foramen (? rudimentary *condylus tertius*)
72	♂		191	194	194	146	101		115		541	359	310	77			57	20	41	40	32·5	33	49	37	75·3		75·3			—	45·6	79·3	82·5	75·5							85	cal. senile. both zygom. arches and centre of base defective. metopic suture nearly closed. bilateral frontal process of squamous temporal. small *torus occipitalis*. traces of ossicles in lambdoid suture
73	♀		170		170	129	94	118	102 h	89	[illegible]	342	283				—										75·9	69·4	109·3	—	-	—	—	—	—	—	—	—	—	—	—	cal. f. y. ad. defects in base, ethmoidal and l. temporal. metopic. extensive flattening of obelion. small bilateral precondylar eminences on basi-occipital
74	♂	1340	176		179	139	98	136	108 h	105	509	351	305											—		-	77·6	76	102·2					—							-	cal. f. y. ad. ossicles in hinder part sagit. suture
75	♂ ?		176	177	178		96	120	[illegible]	96	492	·	[illegible]	72·5	96		52·5	28	41·5	41	33	32	51·5	36		67·8		67·4		75·5	53·3	79·5	78	69·9	90	68	68	44	21	23	89	cal. ad. defective l. zygom., l. parietal and occipito-temporal. negroid appearance ?
76	♂		[illegible]	191	191	134	94	132	110	102	519		294	71			49	22·5		42		34	49	35	70·2	69·1	70·2	69·1	101·5	-	45·9	-	80·9	71·4	100·5	68	71	41	10	31	81	cal. ad. defect frontal and l. side face. irregular line of lambdoid suture
77	♂		[illegible]	192	193	142		131	110	90		392	300	71	88	—	51	23·5	42		34		48	38	74	68·2	73·6	67·9	108·4	80·7	46·1	80·9		79·2	92·5	65·5	71	43·5	17	20·5	88	cal. ad. defect r. frontal and malar
78	♀	1220	170	180	180	130	92	125	[illegible]	97	497	357	287				50	25		41		33·5			72·2	69·4	72·2	69·4	104		50		81·7									cal. ad. defect l. side face
79	♂	[illegible]	[illegible]		200	133	88	133	[illegible] h	104	[illegible]	394	289				—						—				66·5	66·5	100					-		-	-		-			cal. f. old. sagit. sut. completely obliterated
80	♀		164		165	124	91	110	[illegible] h	81	461	334		61	78		44	21	39	40	30·5	30·5	41·5	—			75·1	66·7	112·7	78·2	47·7	78·2	76·2		78	65	70	45			-	cal. y. ad. right temporal defect. wormians in lambdoid suture
81	♂	1415	183	183	183	139	97	133	120	98	513	370	308	70	88		50·5	25	42	42	33	33	46·5	35	76	72·7	76	72·7	104·5	79·5	49·5	78·6	78·6	75·3	91·5	63·5	73	43·5	18	25·5	91	cal. y. ad. l. zygoma defective
82	♂	1475	177		178	149	90	134	113 h	97	517	370	312									-		—		-	83·7	75·3	111·2										-	—		cal. f. y. ad. r. ossicle of pterion
83	♀	1300	178		178	137	[illegible]	123	111 h	92	505	357	290								—		-	-			77	69·1	111·3										—	-		cal. f. y. ad. slight ethmoidal defect, r. ossicle of pterion
84	♂ ?	1300	175	177	177	137	91	126	110	95	500	362	295	70	92	124	52	23·5	41	40·5	32·5	31·5		35·5	77·4	71·2	77·4	71·2	108·7	76·1	45·2	79·3	77·8		89	63	73	44	14	30	87	cal. ad.
85	♀	1305	170	180	181	131	89	126	100	98	[illegible]	307	292	68	76	117	50	20	41	42	34·5	35·5	43		72·8	70	72·4	69·6	103·9	89·5	40	84·1	84·5		85·5	59	78	43	14	29	92	cal. ad. projection 8 mm. long from hinder margin of external pterygoid plate on r. side
86	♀ ?	1305	172	172	173	136	96	131	113	96	495	355	302		88	124	51·5	21	41	39	36	36	45	33·5	79·1	76·2	78·6	75·7	103·8		40·8	87·8	92·3	74·4	—							cal. y. ad. projection 4 mm. long from hinder margin of external pterygoid plate on r. side. metopic suture persisting for 23 mm. at upper end
87	♀		184		184	134	89	118	110 h	88	512	382	291														72·8	64·1	113·5		-				-				—			cal. f. ad. frontal defect
88	♂	-	194		199	140	95	116	110 h	102	530	377	-	69			52·5	24									70·3	58·3	120·6		45·7				97·5	66·5	73·5	40	—	--		cal. ad. r. occipito-temporal defect, face defective on both sides. heavy brow ridges. slight bathrocephaly
89	♂	1600	187		188	143	100	142	120 h	101	522	385	322	--							—				—		76·1	75·5	100·7						--	—						cal. f. ad. slight ethmoidal defect
90	♀		177	175	176	135	91	119	105	88	498	357	287		84		46·5	24	—	37·5	32·5	32·5	41	37·5	77·1	68	76·7	67·6	113·5		51·6		86·7	91·5				—		-	-	cal. old. large occipital defect, both zygomata defective
91	♂	1415	182	183	184	143	97	131	113	97	516	371	308	70	90	127	52·5	24	40·5	41·5	34	34·5	45		78·1	71·6	77·7	71·2	109·2	77·8	45·7	83·9	83·1		93·5	66	71	43	16	27	87	cal. ad. both zygomata defective
92	♀	1100	172		173	131	85	120	102 h	93	485		276			—										—	75·7	69·4	109·2					-	--	—				—		cal. f. ad. small occipital defect
93	♀		174		177	139	87	124	108 h	96	493			-													78·5	70·1	112·1						—	--					—	cal. f. ad. base very defective
94	♂		197		197	140	97		120 h		555	400	332			—					—	-	—	-	-		75·0			—					--	--						cal. f. ad. centre of base defective
95	♀	1305	183		181	135	90	129	113 h	101	566	362	303											-	-		74·6	71·3	104·6					-						-		cal. f. ad. metopic suture persisting for 35 mm. at upper end, traces of trans-occipital suture for about 20 mm. ossicle in fore part l. squamous suture
96	♂	1400	180		180	130	102	132	[illegible] h	107	525	365	302										—	—	—		72	69·8	103													cal. f. ad. slight ethmoidal defect. post parietal flattening and slight depression of obelion. traces of trans-occipital suture for 45 mm. on l. side
97	♀		187		188	136	95		113 h		512	382		66	80		49·5	24·5	40·5	40·5	35	34·5	45	32			72·3			82·5	49·5	86·4	85·2	71·1	-							cal. old. large occipital and l. temporal defect, three ossicles in lambdoid suture, largest 20 × 10 mm.
98	♂		179	180	181	141	96	139	118	97	511	378	311	74	96	131	50	26	41·5	40·5	32·5	33·5	51·5	37·5	78·3	77·2	77·9	76·8	101·4	77·1	52	78·3	82·7	72·8	98·5	69	67	44	15	29	82	cal. ad. right temporal defect

64 Not seen.

MEASUREMENTS OF

TABLE III.

Face							Remarks
J	*NH*	*NB*	O_1 *L*	O_1 *R*	O_2 *L*	O_2 *R*	
129	46	25·5	43	43·5	32·5	33	ad. left mastoid defect. slight post coronal iction [asterion
—	—	—	—	—	—	—	ad. centre of base defective. left ossicle of
—	—	—	—	—	—	—	ad. small l. occipital defect
—	49·5	20	—	—	—	—	ad. both malar regions defective
—	—	—	—	—	—	—	ad. ethmoidal and small l. occipital defect
—	—	—	—	—	—	—	y. ad. ossicle in forepart of squamous suture r.
119	49·5	23·5	42	42	35·5	34·5	ad. metopic
—	—	—	—	—	—	—	y. ad. large occipital, r. temporal and eth- l defects. metopic. small ossicle of λ. 1 × 1 cm.
—	45·5	24	—	38·5	32·5	33	? l. temporal and r. zygoma defective. paired idylar eminences. slight post coronal con- on
—	—	—	—	—	—	—	ad. metopic [precondylar eminences
—	—	—	—	—	—	—	ad. several defects. slight median and paired
—	—	—	—	—	—	—	ad.
—	—	—	—	—	—	—	ad. with large defect, forepart of base. or extremities of condyles united by osseous : see reproduction
—	—	—	—	—	—	—	old. base very defective
—	—	—	—	—	—	—	y. ad. with r. temporo-sphenoidal defect. ossicle of pterion on l.
119	53	24·5	41	41	35	34·5	defective l. zygoma
—	—	—	—	—	—	—	ad. slight depression of obelion
118	—	—	—	—	—	—	r. temporal defect
—	—	—	—	—	—	—	ad. base very defective
—	—	—	—	—	—	—	ad. central defect in base. two ossicles in r. lambdoid suture
—	—	—	—	—	—	—	ad.
135	50	33	44	44·5	31·5	30·5	infra-orbital suture on face, both sides
116	49·5	24·5	42·5	42	35	34·5	defective r. zygomatic arch. post coronal con- on. paired precondylar eminences, left larger
—	49·5	—	41·5	—	31	—	d. r. temporo-frontal and r. half face missing. *s crotaphitico-buccinatorius* (Hyrtl)
—	—		—	—	—	—	ad.
—	51	—	—	44·5	—	37·5	l. side face and frontal defective. slight post l constriction
—	—	—	—	—	—	—	y. ad.
—	—	—	—	—	—	—	ad. forepart base defective
120	49·5	21	40·5	41	33	34	[*cinatorius* . *torus occipitalis*, *incissura crotaphitico-buc-*
109	45	21·5	40	39	33	33	ad. central part base defective
—	—	—	—	—	—	—	y. ad. [defects
—	—	—	—	—	—	—	occipital, slight r. temporal and l. zygomata
—	46	23	41·5	41·5	33·5	33	ad. face very defective
—	—	—	—	—	—	—	occipital and l. temporal defects
130	49·5	22·5	43	41·5	33·5	33·5	ad. slight l. parietal defect. slight bathro-
—	—	—	—	—	—	—	ly. r. precondylar eminence
—	—	—	—	—	—	—	y. ad. two ossicles r. end of lambdoid su- each 15 × 10 mm.
—	—	—	—	—	—	—	ad. defective base
—	—	—	—	—	—	—	ad.
122	50·5	25	—	41·5	—	30·5	defect. l. maxillary. metopic
—	—	—	—	—	—	—	ad. defective base
—	—	—	—	—	—	—	y. ad.
—	—	—	—	—	—	—	ad. metopic; metopic fontanelle. wormian mm. hinder end squamous suture
—	—	—	—	—	—	—	old. fracture of base
—	—	—	—	—	—	—	y. ad. spheno-ethmoidal defect. r. ossicle rion. faint post coronal constriction
—	—	—	—	—	—	—	ad. slight depression of obelion
—	—	—	—	—	—	—	ad. [lambdoid suture
—	51·5	25·5	43	—	34	—	ad. right malar defect. some wormians in
135	51·5	25·5	42	41·5	34·5	35	ossicle in fore part r. squamous suture. enoid produced upwards

MEASUREMENTS OF SEVENTEENTH CENTURY ENGLISH CRANIA.

TABLE III.

Series No.	Sex	C	Lengths								Circumferences			Face									Palate		Indices											Angles						Remarks
			F	L'	L	B	B'	H	OH	LB	U	S	Q	G'H	GB	J	NH	NB	O_1 L	O_1 R	O_2 L	O_2 R	G_1	G_2	B/L'	H/L'	B/L	H/L	B/H	G'H/GB	NB/NH	O_2/O_1 L	O_2/O_1 R	G_2/G_1	GL	N ∠	A ∠	B ∠	θ_2	θ_1	P ∠	
99	♀	—	182	182	182	130	95	127	107	101	498	356	290		90	129	46	25·5	43	43·5	32·5	33		38	71·4	69·8	71·4	69·8	102·3		55·4	75·6	75·9			—						cal. y. ad. left mastoid defect. slight post coronal construction
100	♂		185		186	143	98		120 *h*		527		312	—				–	–		—		—	—	—	—	76·9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. centre of base defective. left ossicle of [asterion
101	♀		170		180	129	89	132	115 *h*	100	498	362	290										—				71·7	73·3	97·7						—							cal. – f. ad small l. occipital defect
102	♀	1260	185		185	132	94	126		101	507	364	292	71	79		49·5	20	—				49	34	-		71·3	68·1	104·8	89·9	40·4			69·4	95	64·5	73	42·5				cal. y. ad both malar regions defective
103	♂	—	189		192	143	95	130	117 *h*	98	527	386	303	—									—		-		74·5	67·7	110			—	—									cal. f. ad. ethmoidal and small l occipital defect
104	♀	1325	179		180	133	87	121	105 *h*	92	499	353	282	-	-			—			—						73·9	67·2	109·9		--		—								-	cal. – f. y. ad. ossicle in forepart of squamous suture r.
105	♀	1245	171	172	171	134	96	119	105	89	489	350	280	70	83	119	49·5	23·5	42	42	35·5	34·5	44·5	30	77·9	69·2	78·4	69·6	112·6	84·3	47·5	84·5	82·1	67·4	83	62	70·5	47·5	10·5	31	87°	cal y. ad. metopic
106	♀		183	—	183	133	103	—	103 *h*	—	510	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	72·7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. y. ad. large occipital, r. temporal and ethmoidal defects. metopic. small ossicle of λ. 1 × 1 cm.
107	♀	—	190	190	190	139	94	121	113	100	525	375	310	62	80		45·5	24		38·5	32·5	33	—	36·5	73·2	63·7	73·2	63·7	114·9	77·5	52·7		85·7		90	62	80	38	15	23	95	cal old l temporal and r zygoma defective. paired precondylar eminences. slight post coronal constriction
108	♀	–	188		188	—	97	—	—	—	525	380	—	—	—	—	—	—	--	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	dome. ad. metopic
109	♀		193		193		97	127	112 *h*	98	522	382	302	-									–	-				65·8				-			-							cal. – f. ad. several defects. slight median and paired [precondylar eminences
110	♂	—	190	—	199	141	100	—	115 *h*	—	541	380	—	—	—	—	—	—	—	—	—	—	-	-	—	—	70·8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	dome. ad.
111	♂	—	188	—	191	—	99	134	113 *h*	109	520	366	306	—	—	—	—	—	—	—	—	—	—	—	—	—	—	70·2	—	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. with large defect, forepart of base. anterior extremities of condyles united by osseous bridge: see reproduction
112	♀	--	185	—	—	129	89	—	—	—	507	—	295	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. old. base very defective
113	♀		186	—	185	141	97	127	106 *h*	95	518	369	—	—	—	—	—	—	—	—	—	—	—	—	—	—	76·2	68·6	111	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. y. ad. with r. temporo-sphenoidal defect. small ossicle of pterion on l.
114	[illegible]	1245	181	180	181	131	98	121	106	101	505	350	288	70·5	85	119	53	24·5	41	41	35	34·5	47	40	72·8	67·2	72·4	66·8	108·2	82·9	46·2	85·4	84·1	85·1	95	64°·5	73°·5	42°	16·5	25·5	90°	cal. ad. defective l. zygoma
115	♂	1410	177		180	140	102	144	120 *h*	103	512	375	314		—												77·8	80	97·2			—										cal. – f. ad. slight depression of obelion
116	[illegible]	—	—	—	—	135	91	—	—	—	-	—	—	—	84	118	—	—	—	—	—	—	45	36·5	—	—	—	—	—	—	—	—	—	81·1	92·5	—	—	—	—	—	—	cal. ad. r. temporal defect
117	♂		184		186	138	93	127	109 *h*	97	515					—	—	—	—	—	—	—	—	—		—	74·2	68·3	108·7			—				—					-	cal. – f. ad. base very defective
118	♀	—	184	—	181	146	93	—	112 *h*	—	519	391	307	—	—	—	—	—	—	—	—	—	—	—	—	—	80·7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. central defect in base. two ossicles in r. end of lambdoid suture
119	♀	1355	182	—	181	138	93	121	106 *h*	91	507	368	293	—	—	—	—	—	—	—	—	—	—	—	—	—	76·2	66·8	114	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad.
120	♂	1400	182	185	184	138	104	137	116	95	513	385	309	65	94	135	50	33	44	44·5	31·5	30·5	48	37·5	74·6	74	75	74·5	100·7	65·9	66	71·6	68·5	78·1	91·5	67°	72°·5	40°·5	9°·5	31°	82°	cal. ad infra-orbital suture on face, both sides
121	♀	1225	180	182	181	128	90	121	103	99	495	350	273	68·5	85	116	49·5	24·5	42·5	42	35	34·5	45	34·5	70·3	66·5	70·7	66·8	105·8	80·6	49·5	82·3	82·1	76·7	93·5	65	73·5	41·5	9·5	32	83°	cal. old defective r. zygomatic arch post coronal constriction paired precondylar eminences, left larger
122	♂		185		180	130		130	112 *h*	104	514	362		61·5			49·5		41·5		31						73·1	69·9	104·6			74·7		-						—	—	cal. y. ad. r. temporo-frontal and r. half face missing. l. *porus crotaphitico-buccinatorius* (Hyrtl)
123	[illegible]	1570	194	—	197	138	100	139	118 *h*	105	535	393	314	—			—		-			—		—			70	70·6	99·3					—	—	-						cal f ad.
124	♂		194	194	195	134		126	112	107		377	393	73			51			44·5		37·5			69·1	64·9	68·7	64·6	106·4				84·3		95·5	66·5	78	41·5	12	29·5	90	cal. old. l. side face and frontal defective. slight post coronal constriction
125	♀	1170	169	—	170	128	94	124	109 *h*	93	484	352	290	—	—	—	—	—	—	—	—	—	—	—	—	—	75·3	72·9	103·2	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. y. ad.
126	♂	—	193	—	—	144	—	136	116 *h*	—	—	—	314	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	105·9	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. forepart base defective
127	♀	1185	172	174	174	127	84	124	106	98	477	343	279	70	83	120	49·5	21	40·5	41	33	34	45	35	73	71·3	73	71·3	102·4	84·3	42·4	81·5	82·9	77·8	90·5	63°	74°	43°	14°	29	88	cal. ad.
128	[illegible]	1130	162	164	164	128	88	116	114	93	471	320	274	55·5	81	109	45	21·5	40	39	33	33	42	35	78	70·7	78	70·7	110·4	68·5	47·8	82·5	84·6	83·3	89	68	70	36	10	26	86	cal. old. *torus occipitalis, incisura crotaphitico-buc- [cinatorius*
129	♂		176	—	177	136	98	—	113 *h*	—	501	353	303	—	—	—	—	—	—	—	—	—	—	—	—	—	76·8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. central part base defective
130	♀	1350	185	—	185	137	94	122	107 *h*	95	512	364	290	—	—	—	—	—	—	—	—	—	—	—			74	65·9	112·3													cal. – f. y. ad.
131	♀	–	168	169	169	133	94	120	102	90	486	345	281	61·5	87		46	23	41·5	41·5	33·5	33		33	78·7	71	78·7	71	110·9	70·7	50	80·7	79·5		85·5	65·5	73·5	41	9·5	31·5	83	cal. ad. occipital, slight r. temporal and l. zygomata [defects
132	♂	—	—	—	—	145	100	142	119	—	525	—	317	—	—	—	—	—	—	—	—	—	52	36·5	—	—	—	—	102·1	--	—	—	—	70·2	89	—	—	—	—	—	—	cal. y. ad. face very defective
133	♂	—	—	—	—	143	100	—	116 *h*	—	-	—	—	73	99	130	49·5	22·5	43	41·5	33·5	33·5	47·5	35						73·7	45·4	77·9	80·7	73·7								cal. ad. occipital and l. temporal defects
134	♀	1505	192		192	144	95	127	115 *h*	98	535	383	313														75	66·1	113·4									-	-	-	-	cal. – f. ad. slight l. parietal defect. slight bathrocephaly. r. precondylar eminence
135	♀	1180	177	—	178	131	93	126	103 *h*	99	495	342	275	—	—	—	—	—	—	—	—	—	—	—	—	—	73·6	70·8	103·9	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. y. ad. two ossicles r. end of lambdoid suture, each 15 × 10 mm.
136	♀	—	176	—	177	142	94	—	108 *h*	—	501	351	296	—	—	—	—	—	—	—	—	—	—	—	—	—	80·2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. defective base
137	♀	—	178	—	180	128	89	—	105 *h*	—	492	354	—	—	—	—	—	—	—	—	—	—	—	—	—	—	71·1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	dome. ad.
138	♂	1305	179	177	177	137	101	132	110	101	497	343	293	68	88	122	50·5	25		41·5	—	30·5	47	35·5	77·4	74·6	77·4	74·6	103·8	77·3	49·5	—	73·5	75·5	94·5	64·5	75	40·5	7	33·5	82	cal. ad defect. l. maxillary. metopic
139	♂	-	183		184	128	[illegible]		[illegible] *h*		497	303	274	-				-		-							69·6				-	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. defective base
140	♀	—	175	—	175	125	89	--	97 *h*	--	482	341	—	—	—	—	—	—	—	—	—	—	—	—	—	—	71·4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	dome. y. ad.
141	♂	1445	179	—	179	142	100	133	114	99	510	367	310	—	—	—	—	—	—	—	—	—	—	—	—	—	79·3	74·3	106·7	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. metopic; metopic fontanelle. wormian 26 × 8 mm. hinder end squamous suture
142	♂	–	205	—	206	146	111	134	120 *h*	—	570	409	331	—	—	—	—	—	—	—	—	—	—	—	—	—	70·9	65	108·9	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. old. fracture of base
143	♀	—	191	—	190	143	103	128	112 *h*	99	538	378	301	—	—	—	—	—	—	—	—	—	—	—	—	—	75·3	67·4	111·7	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. y. ad. spheno-ethmoidal defect. r. ossicle of pterion. faint post coronal constriction
144	[illegible]		181	—	181	145	93	—	109 *h*	—	513	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	80·1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	dome. ad. slight depression of obelion
145	♂	1395	187	—	187	140	97	127	113 *h*	96	525	376	307	—	—	—	—	—	—	—	—	—	—	—	—	—	74·9	67·9	110·2													cal. – f. ad.
146	♂	1445	185	186	185	133	97	137	117	103	511	367	300	66	87		51·5	25·5	43		34		44·5	36	71·5	73·7	71·9	74	97·1	79·3	49·5	79·1		80·9	94	62·5	77	40·5	11	29·5	88	cal. y. ad right malar defect. some wormians in [lambdoid suture
147	♂	1555	189	191	191	148	100	130	114	103	517	370	305	73	99	135	51·5	25·5	42	41·5	34·5	35	47·5	36	77·5	68·1	77·5	68·1	113·9	73·7	49·5	82·1	84·3	75·8	96	63·5	74	42·5	18	24·5	92	cal. ad. ossicle in fore part r. squamous suture. alisphenoid produced upwards

MEASUREMENTS OF

TABLE IV.

	Face					
			O_1		O_2	
J	*NH*	*NB*	*L*	*R*	*L*	*R*
—	—	—	—	—	—	—
17	46·5	21·5	41	40·5	34	34
—	46	22	41	40·5	33·5	33·5
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	52·5	24	44	—	36·5	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	51	24·5	41	41	36·5	37
—	54·5	—	—	—	—	—
40	52	25·5	47	47	35	34·5
25	—	—	—	40·5	—	32
39	50	26	44	44·5	33	31·5
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	38	—	36·5
22	—	—	—	42	35	33
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	51	25	43	43	33	34·5
—	—	—	—	—	—	—
34	—	—	—	—	—	—
	56·5	29	43·5	45	35·5	35
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
25	51	25·5	43	—	34·5	—
—	51·5	23	40	—	32·5	—
—	47·5	—	42	—	34·5	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
36	—	—	—	—	—	—
—	—	—	—	—	—	—
—	52	25·5	45	44·5	35	36
24	52	—	—	40·5	—	35

Remarks
ad. r. temporal defect. aperture in r. frontal
mm. with sloping smooth cicatrized margin
ly result of separation of sequestrum due to
[*tinus*
faint post coronal constriction, *torus pala-*
d. occipital defects; apex of occipital squama
ed. wormians in lambdoid suture
ad. ethmoidal and temporal defects
ad. l. temporal defect. occipital squama
ged upwards
ad. small occipital defect [× 33 longit. mm.
large defects on r. side. ossicle of λ. 50 trans.
y. ad. r. temporal defect and base fractured.
post coronal depression. ossicles in l. lamb-
ture. persistent frontal suture, 3 cms.
ad. *torus occipitalis*
old? some bathrocephaly
ad. slight depression of obelion. faint post
l constriction
d. large temporal defects. faint post coronal
sion. ossicle of pterion bilateral. ossicle in
doid suture and small one in r.
face very defective. post coronal depression
slight temporal defect. l. third molar erupt-
edian prominence 7 mm. wide, 4 mm. high at
r margin of *foramen magnum* (? third condyle)
r. orbit. ad. wormians in outer part of l.
id suture
arge defect in vault. l. pterygo-spinous bridge
ad. very defective base. faint post coronal
d. [constriction
d. l. temporal defect. post coronal depression
l. facial defect. wormians partly united in
d. [l. lambdoid suture
d.
ad. faint post coronal constriction. third oc-
condyle somewhat to l. median ple. low ele-
8 mm. trans. 5 mm. from before back. 5 mm.
nterior margin of foramen magnum, bearing
ar facet
ld
r. malar, l. zygomatic and small r. frontal
flattening of obelion
ad. fronto-ethmoidal defect. very large
left *foramen ovale* subdivided
ad. post coronal constriction. r. ossicle of
bilateral pterygo-spinous bridge
ile. l. zygomatic defect. r. pterygo-spinous
ad. large l. temporo-parietal defect
ad. small r. occipital defect. bilateral ossicle
ld? [of pterion
large defects
d. with r. malar defect
large l. temporo-parietal and r. facial defects.
c; depression of obelion. r. ossicle of pterion
old.
ad. small r. occipital defect. faint post
old? [coronal constriction
ad. with r. sphenoidal defect
ad. metopic; post coronal depression.
y developed inion
r. temporal and occipital defects
l. facial and temporal defects. ossicle of λ.
mm.

MEASUREMENTS OF SEVENTEENTH CENTURY ENGLISH CRANIA.

			Lengths								Circumferences			Face									Palate		Indices											Angles						Remarks
Series No.	Sex	C'	F	L'	L	B	B'	H	OH	LB	U	S	Q	G'H	GB	J	NH	NB	O_1 L	O_1 R	O_2 L	O_2 R	G_1	G_2	B/L'	H/L'	B/L	H/L	B/H	G'H/GB	NB/NH	O_2/O_1 L	O_2/O_1 R	G_2/G_1	GL	N∠	A∠	B∠	θ_2	θ_1	P∠	
148	♂		198		200	140	102	129	117 h	102	542	390	320	—	—	—	—	—	—	—	—	—	—	—	—	—	70	64·5	108·6	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. r. temporal defect. aperture in r. frontal 15 × 15 mm. with sloping smooth cicatrized margin probably result of separation of sequestrum due to injury
149	♀	1315	184	185	185	138	94	121	107	98	513	307	294	68	83	117	46·5	21·5	41	40·5	34	34	47·5	35?	74·6	65·4	74·6	65·4	114	81·9	46·2	82·9	83·9	73·7	94·5	66·5	72	41·5	15	20·5	87	cal. ad. faint post coronal constriction, *torus palatinus*
150	♀		176	175	175	135	97	127	110	95	500	325	265	62	82		46	22	41	40·5	33·5	33·5	46·5	36	77·1	72·6	77·1	72·6	106·3	75·6	47·8	81·7	82·7	77·4	91	67	74	39	9	30	83	cal. y. ad. occipital defects, apex of occipital squama produced. wormians in lambdoid suture
151	♂?		189		190	143	91	132	114 h	102	527	378	308	—	—	—	—	—	—	—	—	—	—	—	—	—	75·3	69·5	108·3	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. ethmoidal and temporal defects
152	♀		185	—	185	140	96	126	114 h	95	517	380	309	—	—	—	—	—	—	—	—	—	—	—	—	—	75·7	68·1	111·1	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. l. temporal defect. occipital squama prolonged upwards
153	♂	1400	187		187	140	98	129	117 h	98	525	379	310	—	—	—	—	—	—	—	—	—	—	—	—	—	74·9	69	108·6	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. small occipital defect
154	♂	–	196		199	139	100	141	122 h	111	537	390		72·5		-	52·5	24	44	-	36·5		54	36			69·8	70·8	98·6	-	45·7	82·9		66·7	105	66°	75°	39°				cal. ad. large defects on r. side. ossicle of λ. 50 trans. × 33 longit. mm.
155	♀		183		183	134	86	—	110 h	—	508	378	—	—	—	—	—	—	—	—	—	—	—	—	—	—	73·2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. y. ad. r. temporal defect and base fractured. slight post coronal depression. ossicles in l. lambdoid suture. persistent frontal suture, 3 cms.
156	♂	1410	185		185	139	93	140	125 h	102	517	380	322	—	—	—	—	—	—	—	—	—	—	—	—	—	75·1	75·7	99·3	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. *torus occipitalis*
157	♂	1585	192		195	144	101	141	124 h	99	541	405	323	—	—	—	—	—	—	—	—	—	—	—	—	—	73·8	72·3	102·1	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. old? some bathrocephaly
158	♀	1315	182		183	135	93	130	116 h	97	509	373	305	—	—	—	—	—	—	—	—	—	—	—	—	—	73·8	71	103·8	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. slight depression of obelion. faint post coronal constriction
159	♀	—	186		186		103	127	110 h	100	519	363	—	74	89	—	51	24·5	41	41	36·5	37	54	35	—	—	—	68·3	—	83·1	48	89	90·2	64·8	100	68°·5	68°·5	43°	—	—	—	cal. y. ad. large temporal defects. faint post coronal depression. ossicle of pterion bilateral. ossicle in l. lambdoid suture and small one in r.
160	♂		190	192	192	138	95	130	111	105	523	378	298	70	—	—	54·5	—	—	—	—	—	43	30·5?	71·9	67·7	71·9	67·7	106·1	—	—	—	—	70·9	96	63°	76°·5	40°·5	—	—	—	cal. ad. face very defective. post coronal depression
161	♂	1405	187	188	188	146	104	135	115	104	532	380	313	71·5	96	140	52	25·5	47	47	35	34·5	47·5	36·5	77·7	71·8	77·7	71·8	108·1	74·5	49	74·5	73·4	76·8	97	64°	75	41	12	29	87	cal. ad. slight temporal defect. l. third molar erupting. median prominence 7 mm. wide, 4 mm. high at anterior margin of *foramen magnum* (? third condyle)
162	♂?	1435	189	190	191	142	93	131	113	107	524	365	297	—	—	125	—	—	—	40·5	—	32	—	—	74·7	68·9	74·3	68·6	108·4	—	—	—	79	—	—	—	—	—	—	—	—	cal. – f. + r. orbit. ad. wormians in outer part of l. lambdoid suture
163	♂	—	190	190	190	153	97		114	103	535			71	87	139	50	26	44	44·5	33	31·5	50·5	41·5	80·5		80·5			81·6	52	75	70·8	82·2	101·5	68·5	71	40·5	15	25·5	80	cal. ad. large defect in vault. l. pterygo-spinous bridge
164	♀		184		184	129	90	—	109 h	—	508	373	292	—	—	—	—	—	—	—	—	—	—	—	—	—	70·1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. very defective base. faint post coronal constriction
165	♀?		180		181	136	94	—	104 h	—	500	355	—	—	—	—	—	—	—	—	—	—	—	—	—	—	75·1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	dome. ad.
166	♀		181		181	132	90	124	109 h	92	500	370		—	—	—	—	—	—	38	—	36·5	—	—	—	—	72·9	68·5	106·5	—	—	—	96	—	—	—	—	—	—	—	—	cal. – f. ad. l. temporal defect. post coronal depression
167	♀	1370	184	184	183	136	96	127	114	103	511	364	297	—	—	122	—	—	—	42	35	33			73·9	69	74·3	69·4	107·1		—		78·6			—						cal. ad. l. facial defect wormians partly united in l. lambdoid suture
168	♂		—			148			115 h				322	-		—									—										—							dome. ad.
169	♂		191		192	142	96	—	—	—	530	370	—	—	—	—	—	—	—	—	—	—	—	—	—	—	74	—	—	—	—	—	—	—	—	—	—	—	—	—	—	dome. ad.
170	♀	1140	176		177	132	95	122	103 h	92	491	352	271	—	-	—	—	—	—	—	—	—	—	—	—	—	74·6	68·9	108·2	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. faint post coronal constriction. third occipital condyle somewhat to l. median ple. low elevation. 8 mm. trans. 5 mm. from before back. 5 mm. from anterior margin of foramen magnum, bearing articular facet
171	♂		180		185	133	91	—	110 h	—	505	364	—	—	—	—	—	—	—	—	—	—	—	—	—	—	71·9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	dome. old
172	♂	1495	192	193	193	140	103	130	114	107	526	373	303	71	—	—	51	25	43	43	33	34·5	49?	37·5	72·5	67·4	72·5	67·4	107·6	—	49	76·7	80·2	76·5	105·5	69°	72°	39°	10°	29°	82°	cal. ad. r. malar, l. zygomatic and small r. frontal defects. flattening of obelion
173	♂		186		187	141	99	134	118 h	107	522	383	308	—	—	—	—	—	—	—	—	—	—	—	—	—	75·4	71·7	105·3	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. fronto-ethmoidal defect. very large inion. left *foramen ovale* subdivided
174	♂	1665	195		196	145	106	137	117 h	102	545	394	318	—	—	134	—	—	—	—	—	—	—	—	—	—	74	69·9	105·8	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. post coronal constriction. r. ossicle of pterion. bilateral pterygo-spinous bridge
175	♂	1470	188	190	190	148	100	130	114	105	535	369	314	71·5	92	—	56·5	29	43·5	45	35·5	35	43·5	—	77·9	68·4	77·9	68·4	113·9	77·7	51·3	81·6	77·8		92·5	59°·5	78°·5	42°				cal. senile. l. zygomatic defect. r. pterygo-spinous bridge
176	♂		184	-	185	139	100	122	109 h	105	516	353	—	—	—	—	—	—	—	—	—	—	—	—	—	—	75·1	65·9	113·9	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. large l. temporo-parietal defect
177	♀	1265	177		179	137	93	127	113 h	94	496	362	300	—	—	—	—	—	—	—	—	—	—	—	—	—	76·5	70·9	107·9						—	—					—	cal. – f. ad. small r. occipital defect. bilateral ossicle of pterion
178	♂?		190		191	139	98				525	360				—	—	—	—	—	—	—	—	—	—	—	72·8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	dome. old?
179	♂		185		188	136	—	125	112 h	103	—	360	—	68·5	89	125	51	25·5	43	—	34·5	—	49	38	-		72·3	66·5	108·8	77	50	80·2		77·5	98	66°	74	40	-			cal. old. large defects
180	♀	1215	176	176	177	129		122	105	93	486	355	280	71·5	81		51·5	23	40		32·5	-	40	33	73·3	69·3	72·9	68·9	105·7	88·3	44·7	81·2		82·5	85	60°·5	72·5	47	16·5	30·5	89	cal. y. ad. with r. malar defect
181	♀		175		175		94	118	102 h	93		342		60			47·5		42	—	34·5	—	39?	—	—	—	—	67·4	—	—	—	82·1	—	—	79	57°	83°	40°	—	—	—	cal. ad. large l. temporo-parietal and r. facial defects. metopic; depression of obelion. r. ossicle of pterion
182	♂?	1260	178		181	137	97	119	107 h	100	505	351	288	—	—	—	—	—	—	—	—	—	—	—	—	—	75·7	65·7	115·1	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. old.
183	♀	1295	183		183	131	89	121	107 h	93	502	365	295	—	—	—	—	—	—	—	—	—	—	—	—	—	71·6	66·1	108·2	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. small r. occipital defect. faint post coronal constriction
184	♀	1180	176		177	132	85	117	107 h	92	486	343	281	—	—	—	—	—	—	—	—	—	—	—	—	—	74·6	66·1	112·9	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. old?
185	♂	—	193		195	141	103	129	117 h	97	540	392	312	—	—	136	—	—	—	—	—	—	—	—	—	—	72·3	66·1	109·3	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. with r. sphenoidal defect
186	♀?		181		181	135	98	—	110 h	—	511	361	—	—	—	—	—	—	—	—	—	—	—	—	—	—	74·6	—	—	—	-	-	-		—	-	—	—	—	—	—	dome. y. ad. metopic; post coronal depression. strongly developed inion
187	♂		185		189	140	95	134	119 h	100	518	378	-	76	91	—	52	25·5	45	44·5	35	36	50·5	36·5			74·1	70·9	104·5	83·5	49	77·8	80·9	72·3	102	69	66·5	44·5	—	—	—	cal. ad. r. temporal and occipital defects
188	♂		185	184	185	139	99	135	113	100	518	377	305	70	90	124	52			40·5	—	35	46	35	75·5	73·4	75·1	73	103	77·8	—	—	86·4	76·1	87·5	59°	78°	43°	—	—	—	cal. ad. l. facial and temporal defects. ossicle of λ. 15 × 10 mm.

MEASUREMENTS

TABLE V.

Face							Remarks
J	*NH*	*NB*	O_1 *L*	O_1 *R*	O_2 *L*		
—	48	25	—	40·5	31·5	3	ad. l. malar and temporal defects. metopic; t depression of obelion
—	—	—	—	—	—		old ? sphenoidal and l. temporal defects
—	—	—	—	—	—		y. ad. spheno-ethmoidal and r. temporal de- considerable l. precondylar eminence. faint coronal depression
—	—	—	—	—	—		y. ad. marked post coronal constriction. small r. jugular foramen. minute r. par- ital process
—	—	—	—	—	—		ad. faint post coronal depression
—	—	—	—	—	—		defective
—	—	—	—	—	—		ad. very imperfect
—	—	—	—	—	—		ad.
—	51·5	26	41·5	42	33	34	nd forepart skull. old ?
—	—	—	—	—	—		ad. very imperfect. metopic. coronal de- [pression
—	—	—	—	—	—		ad. very large. slight depression of obelion
133	52	24·5	46·5	45·5	35·5	3	d. heavy brow ridges
—	—	—	—	—	—		old ? faint depression of obelion
—	—	—	—	—	—		ad. *torus occipitalis*
—	48·5	24	42	42	35	3	large r. temporo-parietal defect
—	—	—	—	—	—		y. ad. sutures complicated. slight post coronal [depression
127	51	24·5	42	41·5	31·5	3	ad. defect in r. superior maxilla. l. infra al suture on face
—	47·5	22·5	—	40	—	3	l. temporal, facial and r. zygomatic defects. a *occipitalis* pentagonal
115	50	26	42	42	35·5	37	d. occipital and r. temporal defects. slight oronal constriction. nearly complete l. pterygo- us bridge
119	—	—	—	—	—		ad. r. temporal and l. sphenoid defects. slight oronal depression. ossicle of λ, 13 × 10 mm.
—	48·5	23	41·5	42	35·5	3	large r. occipito-temporal defect. slight post al depression. bilateral precondylar eminences
—	50·5	24	44·5	42	34	3	ad. r. parietal defect. faint post coronal [constriction
122	48	22·5	44	44	34·5	3	
132	54	24	46	45	37	3	large r. ossicle of pterion, 41 × 12 mm. r. fronto-sphenoidal ossicle ? ossicles of loid suture on both sides especially r. flatten- ad depression of obelion
—	—	—	—	—	—		ad. l. ossicle of pterion. bilateral precondylar nces (double third condyle). faint post coronal ssion
—	—	—	—	—	—		ad. r. fronto-sphenoidal defect. l. precondylar nce. ossicles of Riolan
125	44·5	22	44	43·5	35	34	flattening of obelion. small ossicle of λ, [10 × 10 mm.
—	—	—	—	—	—		ad. frontal defect. division of l. parietal bone, ior inferior part cut off by sinuous suture, g l. lambdoid at junction of inner ⅖ths, with ⅗ths, and joining middle of left squamous; de- l portion 63 mm. from apex to base and 45 mm. base, which abuts against temporal bone
—	—	—	—	—	—		ad. fractured l. parietal. faint post coronal sion. well marked interparietal
129	50·5	20·5	43	42·5	33	3	ad. transverse fracture of base. slight post l depression. median element (*os pentagonale*) erparietal fused with supra-occipital, lateral nts (*ossa triangularia*) distinct
—	47·5	24	43	—	32·5		ad. r. malar defect. interparietal, median *tagonale* and r. *os triangulare* elements free. *triangulare* fused. wormian in l. lambdoid. d occipital projection
125	50·5	20	41·5	40·5	33	3	traces of *os pentagonale*, *ossa triangularia* with parietals ? slight occipital prominence
—	—	—	—	—	—		ad. slight sagittal ridge. interparietal, median nt (*os pentagonale*) free; l. *os triangulare* r. very small, 20 × 25 mm.

MEASUREMENTS OF SEVENTEENTH CENTURY ENGLISH CRANIA.

TABLE V.

Series No.	Sex	C	Lengths								Circumferences			Face									Palate		Indices											Angles						Remarks
			F	L'	L	B	B'	H	OH	LB	U	S	Q	G'H	GB	J	NH	NB	O_1 L	O_1 R	O_2 L	O_2 R	G_1	G_2	B/L'	H/L'	B/L	H/L	B/H	G'H/GB	NB/NH	O_2/O_1 L	O_2/O_1 R	G_2/G_1	GL	N∠	A∠	B∠	θ	$θ_1$	P∠	
189	♀		180	178	178	132	95	121	110	95	504	353	296	66·5	81		48	25		40·5	31·5	32	49	38	74·2	68	74·2	68	109	82·1	52·1		79	77·5	94	69	70	41	18	23	88	cal. y ad. l. malar and temporal defects metopic; slight depression of obelion
190	♀	-	186	-	185	138	94	132	113 h	99	515	375									-	-					74·6	71·3	104·6							-						cal f. old? sphenoidal and l temporal defects
191	♀		177	-	177	128	93	122	108 h	91	493	363	290							-	—	-	-	—			72·3	68·9	104·9						-							cal f y. ad. spheno-ethmoidal and r. temporal defects considerable l. precondylar eminence. faint post coronal depression
192	♂ ?	1260	176		178	136	93	125	107 h	97	493	354	291	-		—	—							-		-	76·4	70·2	108·8		-			--	-	-						cal. - f. y. ad. marked post coronal constriction. very small r. jugular foramen. minute r. paroccipital process
193	♀	1375	174	-	174	141	91	120	110 h	91	505	360	299										-	—	–		81	69	117·5		-		-			-						cal f ad faint post coronal depression
194	♀		183		182	132		125	-	95		370	294						-			—			—		72·5	68·7	105·6				-	-	- -	-		-		—		dome. defective
195	♀	—	179		179	129	98		110 h			370															72·1								-	-						cal. f. ad. very imperfect
196	♀	-	191		192	136	94		112 h		522	376		—								—	-				70·8	—							-	-		-				dome. ad.
197	♀					-			114 h					67·5	86		51·5	26	41·5	42	33	34	46	39						78·5	50·5	79·5	80·9	84·8	—	-		-			—	upper and forepart skull. old?
198	♂	-	186	—	181		106	127	108 h	107		352																70·2													—	cal f ad. very imperfect. metopic. coronal depression
199	♂	-	192		192	158	102		124 h		553	389													—		82·3															dome ad. very large. slight depression of obelion
200	♂	1440	189	192	193	135	97	137	116	105	520	380	305	72		133	52	24·5	46·5	45·5	35·5	35·5	50	40	70·3	71·3	69·9	71	98·5		47·1	76·3	78	80	99·5	65	73·5	41·5	10·5	31	84	cal old. heavy brow ridges
201	♀	-	186	—	181	133	89				499	357	-														73·5								—						—	dome old? faint depression of obelion
202	♀	-	187		180	138	93				506														—		76·7															dome ad. *torus occipitalis*
203	♀	-	181	179	180		99	128	112	92	-	307	293	64	86		48·5	24	42	42	35	35·5	39	32		71·5		71·1	-	74·4	49·5	83·3	84·5	82	83·5	61·5	76	42·5	13	29·5	89	cal. ad large r. temporo-parietal defect
204	♂		192		195	130	95	122		112	[illegible]	[illegible]	-														66·7	62·6	106·6													dome. y. ad. sutures complicated. slight post coronal depression
205	♂	1260	[illegible]	176	177	135	94	130	107	99	497	348	[illegible]	74	86	127	51	24·5	42	41·5	31·5	32		35	76·7	73·9	76·3	73·4	103·8	86	48	75	77·1		96	65·5	70	44·5	13	31·5	83	cal y ad. defect in r. superior maxilla. l. infra orbital suture on face
206	♀		192		193		87	128	114 h	98	522	388		68			47·5	22·5	—	40	-	33	46	32	–			66·3			47·4		82·5	69·6	91	63	75	42		–		cal. ad. l. temporal, facial and r. zygomatic defects. *norma occipitalis* pentagonal
207	♀		179		181	123	91		107 h		489	353		65	79	115	50	26	42	42	35·5	37·5		--	—		68			82·3	52	84·5	89·3	—	—	—		-	-	-	-	cal. old. occipital and r. temporal defects. slight post coronal constriction. nearly complete l. pterygo-spinous bridge
208	[illegible]		173		173		94	127	[illegible]	99	493	347	293			110												73·4							-	-				-		cal. – f. ad. r. temporal and l. sphenoid defects. slight post coronal depression ossicle of λ, 13 × 10 mm.
209	♀	-	181		181	136	92	123	114 h	93	505	[illegible]		69·5	81		48·5	23	41·5	42	35·5	35·5	42	36			75·1	68	110·6	85·8	47·4	85·5	84·5	85·7	91	66·5	70	43·5				cal. ad large r occipito-temporal defect. slight post coronal depression. bilateral precondylar eminences
210	♂	—	183	185	185	-	96	126	108	96	520	368	207	65	92		50·5	24	44·5	42	34	32	47·5	36·5		68·1		68·1		70·6	47·5	76·4	76·2	76·8	96	70	70	40	12	28	82	cal. y. ad. r parietal defect. faint post coronal constriction
211	[illegible]		184	185	186	132	[illegible]	121	[illegible]	[illegible]	502	354	276	68	86	122	48	22·5	44	44	34·5	35	48	35	71·3	65·4	71	65	109	79·1	46·9	78·4	79·5	72·9	100	71	69	40	11	29	80	cal. ad.
212	♂	1605	194	195	196	148	102	142	116	108	547	[illegible]	317	73	105	132	54	24	46	45	37	38	48·5	34	75·9	72·8	75·5	72·4	104·3	69·5	44·4	80·4	84·4	70·1	97	61	77·5	41·5	6·5	35	84	cal ad. large r ossicle of pterion, 41 × 12 mm. small r. fronto-sphenoidal ossicle? ossicles of lambdoid suture on both sides especially r. flattening and depression of obelion
213	[illegible]	[illegible]	[illegible]		200	142	[illegible]	137	123 h	[illegible]	545	[illegible]	323										-		-	·	71	68·5	103·6						—							cal. f. ad. l ossicle of pterion. bilateral precondylar eminences (double third condyle). faint post coronal depression
214	♀		172		174	126	[illegible]	125	106 h	[illegible]	[illegible]	344	272				–		–	–							72·4	71·8	100·8						- -							cal. f. ad. r. fronto-sphenoidal defect. l. precondylar eminence. ossicles of Riolan
215	♂ ?	1535	187	188	187	145	[illegible]	123	117	95	530	[illegible]	[illegible]	64	86	125	44·5	22	44	43·5	35	34	48	34·5	77·1	65·4	77·5	65·8	117·9	74·4	49·4	79·5	78·2	71·9	92	67	73	40	17	23	90	cal. ad. flattening of obelion. small ossicle of λ, 10 × 10 mm.
216	♀		[illegible]		182	142	91	121	108 h	92	512	355	207														78	66·5	117·4													cal. f ad. frontal defect. division of l. parietal bone, posterior inferior part cut off by sinuous suture, leaving l. lambdoid at junction of inner ⅔ths, with outer ⅓ths, and joining middle of left squamous; detached portion 63 mm. from apex to base and 45 mm. across base, which abuts against temporal bone
217	♂	1400	186		188	145	[illegible]	120	111 h	99	525	378	300										—		-		77·1	63·8	120·8					—							—	cal. - f. ad. fractured l. parietal. faint post coronal depression. well marked interparietal
218	♂		190	188	190	145	[illegible]	135	112	99	[illegible]	382	300	68	97	129	50·5	20·5	43	42·5	33	33·5	50	40·5	77·1	71·8	76·3	71	107·4	70·1	40·6	76·7	78·8	81	100	70·5	69·5	40	7·5	32·5	77	cal. y. ad. transverse fracture of base. slight post coronal depression. median element (*os pentagonale*) of interparietal fused with supra-occipital, lateral elements (*ossa triangularia*) distinct
219	♀ ?	1450	193	191	192	135	102	132	112·5	96	530	385	300	63			47·5	24	43		32·5		47·5	32·5	70·7	69·1	70·3	68·7	102·2	-	50·5	75·6	-	68·4	88·5	64	77	39	10	29	87	cal y. ad. r. malar defect. interparietal, median *os pentagonale* and r. *os triangulare* elements free. l. *os triangulare* fused. wormian in l. lambdoid. marked occipital projection
220	[illegible]	1410	182	181	182	143	[illegible]	125	115	92	[illegible]	375	307	68	78	125	50·5	20	41·5	40·5	33	33	43·5	32	79	69·1	78·6	68·7	114·4	87·2	39·6	79·5	81·5	73·6	84·5	61·5	73·5	45	20·5	24·5	94	cal. ad. traces of *os pentagonale*, *ossa triangularia* fused with parietals? slight occipital prominence
221	♂	-	180		192	138	94	128	114 h	101	525	382	299				-	-									71·9	66·7	107·9	-	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. slight sagittal ridge. interparietal, median element (*os pentagonale*) free; l. *os triangulare* fused, r. very small, 20 × 25 mm.

MEASUREMENTS OF TABLE VI.

Face							Remarks
J	NH	NB	O_1 L	O_1 R	O_2 L	O_2 R	
—	—	—	—	—	—	—	ad. heavy brow ridges. interparietal, *os* *gonale* distinct, *ossa triangularia* fused. slight ndylar eminences
—	—	—	—	—	—	—	ad. ethmoidal defect. platybaric. consider- ossicle of λ, 26 × 20 mm. faint post coronal ssion
—	—	—	—	—	—	—	ad. ossicle of λ, 33 × 28 mm. and other es in lambdoid suture
—	—	—	—	—	—	—	ad. very defective base. ossicle of λ, 5 mm. faint post coronal depression
—	—	—	—	—	—	—	ad. marked post coronal constriction. paired es of λ, each about 20 × 15 mm. some occi- prominence. wormians, chiefly in r. lamb- suture
—	—	—	—	—	—	—	ad. traces of ossicle of bregma, 20 × 13 mm.
—	—	—	—	—	—	—	ad. very defective base. ossicle of bregma, o mm. r. parietal flattening
131	55	25	47	47·5	38	39	l. and r. parietal defects. *hamulus lacry-* reaches face
—	—	—	—	—	—	—	ad. with basal and left temporal defects. cephalic, wormian, 15 × 15 mm. in l. coronal e [depression of obelion
—	—	—	—	—	—	—	y. ad. marked plagiocephaly; r. side smaller.
—	—	—	—	—	—	—	ad. plagiocephalic, r. occipital and l. frontal ning. r. post coronal depression
—	—	—	—	—	—	—	ad. large occipital defect. slight post coronal ssion. interparietal, *os pentagonale* and l. *os* *ulare* distinct, r. *os triangulare* missing
139	52·5	28	44	43	34·5	32·	robust and powerful
127	50	22	42·5	42	32·5	32·	(? y.) metopic. forehead peculiarly in- e in character, slight bathrocephaly. ossicle 17 × 20 mm. and other ossicles in lambdoid e, slight coronal depression
—	52·5	23·5	40	40	31·5	33·	zygomatic arches defective
—	51·5	23	43·5	—	33	—	ad. r. zygomatic arch and outer wall of orbit ive. upper r. canine coming through behind l incisor
124	49	24·5	—	41·5	33	32·	l. orbit imperfect. very pronounced bathro- ly. large ossicles in lambdoid suture. lozenge d ossicle of bregma, 60 × 50 mm.
120	51·5	27	40·5	41·5	34	33·	slight groove of obelion [wards 6 mm.
—	52	21	44·5	44	34·5	34	l. zygoma defective, inion projects down-
—	—	—	—	—	—	—	ad. slight defect occipital bone
117	50·5	26	42	44	35·5	36·	r. zygoma defective
128	51·5	23	43·5	43	31·5	30·	
—	54·5	23	43	—	34	—	? zygomatic arch, outer wall of orbit and a defective on r. side, heavy powerfully built with strong brow ridges and inion
—	52	22·5	40	39·5	34·5	33	(? y.) left zygoma defective. infantile type. ossicles in lambdoid suture. slight flattening lion
—	—	—	—	—	—	—	old. small defects in both temporal regions. sis pedunculated 30 mm. long × 18 mm. broad cipital region
—	52	22	—	41	34	34	l. malar region defective. large defect in tal. small defect in region of obelion, pro- due to injury ante mortem. *os interparietale,* *tagonale* and l. *os triangulare* distinct. r. *os* *lare* apparently absent; place supplied by of parietal pentagonal and especially supra- al
15	45	26	42	40·5	31	30	d.
—	—	—	—	—	—	—	ad. ethmoidal defect
—	48	24	43	41·5	31	33	both zygomata defective [lambdoid suture
35	51	25	44	43	31	31	trace of bathrocephaly. small ossicles in

seen.

MEASUREMENTS OF SEVENTEENTH CENTURY ENGLISH CRANIA.

TABLE VI.

Series No.	Sex	C	Lengths F	L	l	B	B′	H	OH	LB	Circumferences U	S	Q	Face G′H	GB	J	NH	NB	O₁ L	O₁ R	O₂ L	O₂ R	Palate G₁	G₂	Indices B/L′	H/L′	B/L	H/L	B/H	G′H/GB	NB/NH	O₂/O₁ L	O₂/O₁ R	G₂/G₁	GL	Angles N∠	A∠	B∠	θ₂	θ₁	P∠	Remarks
222	♂	1225	185		180	121	94	137	114 h	109	493	370	290	—		—	—	—		—		—					65	73·7	88·3			—							—	—	—	cal. – f. ad. heavy brow ridges. interparietal, *os pentagonale* distinct, *ossa triangularia* fused. slight precondylar eminences
223	♀	1330	178		181	147	100	121	112 h	95	514	304	305							—	—	—		—	—		81·2	66·8	121·5							—			—	—	—	cal. – f. ad. ethmoidal defect. platybaric. considerable ossicle of λ, 26 × 20 mm. faint post coronal depression
224	♀	1300	174		174	139	95		116 h	90	498	359	320	—											—		79·9					—		—		—					—	cal. – f. ad. ossicle of λ, 33 × 28 mm. and other ossicles in lambdoid suture
225	♂		189		189	137	96	127		94	522	379		—								—	—	—	—		72·5	67·2	107·9				—	—		—					—	cal – f ad. very defective base. ossicle of λ, 17 × 15 mm. faint post coronal depression
226	♀	—	181		181	134	91		—		502	367		—			—					—	—	—	—		74	—		—				—	—	—	—		—		—	dome. ad. marked post coronal constriction. paired ossicles of λ, each about 20 × 15 mm. some occipital prominence. wormians, chiefly in r. lambdoid suture
227	♂	1485	188		188	137	96	129	112	101	517	383	297	—									—			—	72·9	68·6	106·1			—			—						—	cal. – f. ad. traces of ossicle of bregma, 20 × 13 mm.
228	♂		182		187	129	90	134	108 h	106	505	365	281										—	—			69	71·7	96·2					—	—						—	cal. – f. ad. very defective base. ossicle of bregma, 20 × 20 mm. r. parietal flattening
229	♂		182	182	183	141	95	124	108	100	512	353	304	73·5	89	131	55	25	47	47·5	38	39	45·5	38	77·5	68·1	77	67·8	113·8	82·6	45·4	80·8	82·1	83·5	90	60	74·5	45·5	15·5	30	90	cal. ad. l. and r. parietal defects. *hamulus lacrymalis* reaches face
230	♂	—	187		189	143	103	141	115 h	99	530	380	—					—		—	—	—	—			—	75·7	74·6	101·4		—										—	cal. – f. ad. with basal and left temporal defects. plagiocephalic, wormian, 15 × 15 mm. in l. coronal suture [depression of obelion
231	♀	1235	175			135	93	129	112 h		495		—							—		—			—				104·6												—	cal. – f. y. ad. marked plagiocephaly; r. side smaller.
232	♂	—	190	—	201	148	94				550	390								—		—	—				73·6				—											dome. ad. plagiocephalic, r. occipital and l. frontal flattening. r. post coronal depression
233	♀		—			132	94	116	103 h	92			282					—							—				113·8		—										—	cal. – f. ad. large occipital defect. slight post coronal depression. interparietal, *os pentagonale* and l. *os triangulare* distinct, r. *os triangulare* missing
7037	[illegible]		191	191	191	138	101	120	113	100	527	386	309	75	103	139	52·5	28	44	43	34·5	32·5	49	43	72·2	67·5	71·5	66·8	106·9	72·8	53·3	78·4	75·6	87·8	93·5	62·5	72	45·5	16	29·5	88	cal. ad. robust and powerful
7038	♀	1540	188	186	186	142	97	133	116	98	527	385	312	67·5	96	127	50	22	42·5	42	32·5	32·5	45	40	76·3	71·5	76·3	71·5	106·7	70·3	44	76·5	77·4	88·9	91·5	64	74	42	14	28	88	cal. ad. (? y.) metopic. forehead peculiarly infantile in character, slight bathrocephaly. ossicle of λ, 17 × 20 mm. and other ossicles in lambdoid suture, slight coronal depression
7040	♀	1460	183	183	184	138	87	129	111	99	513	375	304	70	91		52·5	23·5	40	40	31·5	33·5	47·5	34·5	75·4	70·5	75	70·1	106·9	76·9	44·8	78·7	83·7	72·6	96	66·5	71·5	42	12·5	29·5	84	cal. ad. zygomatic arches defective
7041	♂	—	187	190	191	149	99	134	117	100	540	380	325	72	91	—	51·5	23	43·5		33		48	37	78·4	70·5	78	70·2	111·2	79·1	44·7	75·9		77·1	104·5	69	71	40	12	28	83	cal. y. ad. r. zygomatic arch and outer wall of orbit defective. upper r. canine coming through behind lateral incisor
7042	♀	1575	188	189	189	144	91	133	122	93	523	400	329	67	87	124	49	24·5	—	41·5	33	32·5	44·5	39	76·2	70·4	76·2	70·4	108·2	77	50	—	78·3	87·6	85	61·5	74·5	44	19·5	24·5	94	cal. ad. l. orbit imperfect. very pronounced bathrocephaly. large ossicles in lambdoid suture. lozenge shaped ossicle of bregma, 60 × 50 mm.
7044	♀	1235	177	176	177	132	98	126	106	98	498	348	285	75	90	120	51·5	27	40·5	41·5	34	33·5	48·5	34·5	75	71·6	74·6	71·2	104·8	83·3	52·4	83·9	80·7	71·1	94	64	70	46	13	33	83	cal. ad. slight groove of obelion [wards 6 mm.
7045	♂	1570	190	192	193	146	94	132	120	108	536	382	321	73	95		52	21	44·5	44	34·5	34	48	37	76	68·7	75·6	68·4	110·6	76·8	40·4	77·5	77·3	77·1	97·5	61·5	77	41·5	17	24·5	94	cal. ad. l. zygoma defective, inion projects down-
7046	♀	1290	178		178	138	94	120	107 h	91	503	350	288									—					77·5	67·4	114·9			—			—							cal. – f. ad. slight defect occipital bone
7047	♀	1230	178	178	178	134	93	124	107	97	500	355	288	70	83	117	50·5	26	42	44	35·5	30·5	48·5	33·5	75·3	69·7	75·3	69·7	108·1	84·3	51·5	84·5	82·9	69·1	94·5	66·5	70·5	43	12·5	30·5	83	cal. ad. r. zygoma defective
7048	♂	1375	186	188	188	140	96	124	110	99	518	368	302	67·5	89	128	51·5	23	43·5	43	31·5	30·5	47·5	37	74·5	66	74·5	66	112·9	75·8	44·7	72·4	70·9	77·9	96	67·5	72	40·5	16	24·5	88 ?	cal. ad.
7049	♂	1400	192	197	197	141	96	133	116	104	532	393	307	75			54·5	23	43		34	—	47·5	41	71·6	67·5	71·6	67·5	106		42·2	79·1		86·3	93	60	70	44	16	28	92	cal. old? zygomatic arch, outer wall of orbit and maxilla defective on r. side, heavy powerfully built skull with strong brow ridges and inion
7050	♀	1305	181	180	181	137	84	128	112	93	503	367	310	72	81		52	22·5	40	39·5	34·5	33	45	34·5?	76·1	71·1	75·7	70·7	107·1	88·9	43·3	86·2	83·5	76·7	87·5	63	70·5	40·5	17·5	29	88	cal. ad. (? y.) left zygoma defective. infantile type. small ossicles in lambdoid suture. slight flattening of obelion
7051	♀	1455	193			137	90	125	113 h		528	—	301	—		—						—	—		—				109·6	—				—	—	—		—	—			cal. – f. old. small defects in both temporal regions. exostosis pedunculated 30 mm. long × 18 mm. broad in l. occipital region
7052	♂	—	193	191	193	142		132	115	98		394	309	72			52	22		41	34	34	49	40	74·3	69·1	73·6	68·4	107·5	—	42·3		82·9	81·6	98	68·5	68·5	43	14·5	28·5	83	cal. ad. l. malar region defective. large defect in r. frontal. small defect in region of obelion, probably due to injury ante mortem. *os interparietale*, *os pentagonale* and l. *os triangulare* distinct. r. *os triangulare* apparently absent; place supplied by growth of parietal pentagonal and especially supraoccipital
7053	♀	1500	192	190	191	135	95	127	115	96	527	393	306	66	85	115	45	26	42	40·5	31	30		36	71	66·8	70·7	66·5	106·3	77·6	57·8	73·8	74·1	—	94	68	71	41	18	23	89	cal. y. ad.
7054	[illegible]	1500	194		193	137	97	132	114 h	93	533	392	299		—	—	—		—					—	—	—	71	68·4	103·8	—			—		—	—						cal. – f. ad. ethmoidal defect
7055	♂	1410	181	180	182	144	107	132	116	96	522	372	317	68	93	—	48	24	43	41·5	31	33	47·5	40·5	80	73·3	79·1	72·5	109	73·1	50	72·1	79·5	85·3	91	65	73	42	15	27	88	cal. ad. both zygomata defective [lambdoid suture
7056	♂	1545	[illegible]	192	192	137	[illegible]	138	116	103	521	380	301	66	89	135	51	25	44	43	31	31	48·5	36·5	71·3	71·9	71·3	71·9	99·3	74·2	49	70·4	72·1	75·3	96·5	65·5	76	38·5	8	30·5	84	cal. old. trace of bathrocephaly. small ossicles in

7039 not seen.

7043 a Negro skull.

MEASUREMENTS

TABLE VII.

Face						Remarks
NH	*NB*	O_1 *L*	O_1 *R*	O_2 *L*	O_2 *R*	
47·5	25	39·5	40	33	33	
49	26·5	—	43·5	—	32·5	side of face defective. metopic. bathro-
						numerous ossicles in lambdoid suture
56·5	25	—	43	35	36·5	? l. malar defect. strongly bathroce-
						merous ossicles in λ
49·5	24	41	41	34	34	all defect in r. frontal. metopic. slight
						projection. bilateral pterygo-spinous
						aint coronal depression on r. side
49	24	39·5	—	36·5	—	. malar defect. post coronal depression.
						rocephaly. wormians in lambdoid suture,
						two on r., one in parietal notch of
						n each side. infantile forehead
54	23·5	44	—	34	—	. malar defect. inion strongly marked
51	23·5	45	45·5	34	33	rontal, occipital and zygomatic defects
49	22·5	43	42·5	36	35	. zygomatic defect
48·5	21	40·5	42	32	33	l. zygomatic and r. temporal defects.
						ure absent, coronal and lambdoid sutures
						erdolichocephalic, slight coronal depres-
48	23	42·5	41·5	34	34·5	
53·5	22	—	44	—	35	alar defect. ossicles in lambdoid suture
52	23·5	41	40·5	32	32·5	d). minute ossicles in lambdoid suture.
						marked
54	22	41·5	40·5	33·5	34	gomatic arch broken. ossicle of pterion.
						nterparietal bone. *torus occipitalis*
47	22	40	39	32	30·5	ove of obelion, traces of ossicle of λ.
						f pterion. slight *torus occipitalis*
45	24	41·5	43	32	33	
45	22	42	41	33·5	35	zygomatic defect. ossicles of asterion,
						mm., l. 11 × 11 mm. inion well de-
48	23·5	42	42·5	33	33·5	l). r. zygomatic defect [veloped
53	22·5	44	43·5	33·5	34	e r. temporal and orbital defect
50	—	—	39·5	31?	30	ontal and l. facial defects. slight groove
						. *torus occipitalis.* ossicles of lamb-
						e
—	—	—	—		—	r. temporal defect. ossicle 20 × 17 mm.
						oid suture
53·5	24	41	40·5	32	33·5	ad.). slight post coronal depression.
						cess of squamous on both sides
56·5	19·5	45·5	47	39	40	coronal groove. metopic
48	23	40?	40?	34?	33?	l. temporal and occipital defects. slight
						al depression. r. occipital flattening
51	27	45	45	32·5	32	races of ossicle of bregma
44·5	24	41	42	32·5	33·5	. zygomatic and occipital defects
—	—	—	—	—	—	extensive temporo-sphenoidal defect.
						athrocephaly. numerous ossicles of λ
						o-mastoid sutures. ossicle 12 × 12 mm.
						al. slight *torus occipitalis*
51	21·5	43	42	33	33·5	temporal and r. zygomatic defects
45·5	23·5	42	42·5	30·5	30	ed fracture crossing hinder part l. parietal.
						occipitalis
49	23	45	46	30·5	30	ad.). post coronal depression. bulging
						l portion of coronal suture on either side
48·5	25	—	40·5	34	34·5	large basal and l. malar defects
53	22	40·5	40	34·5	34	opic. faint depression of obelion
42	20·5	38	37·5	31	31	
46	24	39·5	40	31·5	30	emporal defect. metopic. post coronal
						. small r. ossicle of pterion and small
						lambdoid suture
57·5	28	43	44	36·5	35·5	ygoma defective
46·5	27	43·5	43	34	33	ccipito-parietal defect
51·5	25	44	43·5	38	36	
45·5	22·5	42·5	43	34·5	35	efective l. zygoma. edentulous save for
						canine. post coronal constriction. *torus*

7062—7088 : th

MEASUREMENTS OF SEVENTEENTH CENTURY ENGLISH CRANIA.

TABLE VII.

Series No.	Sex	C	Lengths F	L	L	B	B'	H	OH	LB	Circumferences U	S	Q	Face G'H	GB	J	NH	NB	O₁ L	O₁ R	O₂ L	O₂ R	Palate G₁	G₂	Indices B/L'	H/L'	B/L	H/L	B/H	G'H/GB	NB/NH	O₂/O₁ L	O₂/O₁ R	G₂/G₁	GL	Angles N∠	A∠	B∠	θ₂	θ₁	P∠	Remarks
7057	♀	1155	179	181	180	128	93	122	105	100	493	352	278	57	85	119	47·5	25	39·5	40	33	33	—	40	70·7	67·4	71·1	67·8	104·9	67·1	52·6	83·5	82·5	—	94	67°	79°	34°	8°	26°	87°	cal. senile
7058	♂	1600	191	189	189	153	109	130	115	100	553	385	310	71	—	—	49	20·5		43·5		32·5		38·5	80·9	72	80·9	72	112·5		54·1		74·7		96	65°·5	72°	42°·5	11°	31°·5	83°	cal. ad left side of face defective metopic. bathrocephalic; numerous ossicles in lambdoid suture
7059	[illegible]	1425	196	196	196	138	99	128	112	98	540	389	299	74	-	—	56·5	25	—	43	35	36·5	49·5	35·5	70·4	65·3	70·4	65·3	107·9	—	44·2	—	84·9	71·7	92	63°	71°	46°	19°	27°	90°	cal. y. ad.? l. malar defect. strongly bathrocephalic, numerous ossicles in λ
7060	[illegible]	1355	179	180	181	137	101	132	114	99	505	366	304	62·5	89	133	49·5	24	41	41	34	34	46	38·5	76·1	73·3	75·7	72·9	103·8	70·2	48·5	82·9	82·9	83·7	90·5	63°·5	78°·5	38°	7°·5	30°·5	86°	cal. ad. small defect in r. frontal. metopic. slight occipital projection. bilateral pterygo-spinous bridge. faint coronal depression on r. side
7061	[illegible]	1332	182	183	182	134	96	121	111	95	515	362	300	61?	—	—	49	24	39·5	—	36·5	—	42·5	36·5	73·2	66·1	73·6	66·5	110·7	—	49	92·4	—	85·9	89·5	66°	76°	38°	14°	24°	90 ?	cal. old. r. malar defect. post coronal depression. slight bathrocephaly. wormians in lambdoid suture, one on l., two on r., one in parietal notch of temporal on each side. infantile forehead
7089	♂	1580	184	187	187	148	92	133	118	102	528	377	320	76	—	—	54	23·5	44	—	34	—	50	31·5	79·1	71·1	79·1	71·1	111·2	—	43·5	77·3	—	63	90	58°·5	75°·5	46°	17°·5	28°·5	93°	cal. old. r. malar defect. inion strongly marked
7090	[illegible]	1305	182	185	185	140	98	118	108	98	512	358	307	66	—	—	51	23·5	45	45·5	34	33	44·5	36·5	75·7	63·8	75·7	63·8	118·6	—	46·1	75·6	72·5	82	91·5	64°·5	75°	40°·5	14°	26°·5	89°	cal. old. frontal, occipital and zygomatic defects
7091	[illegible]	1100	180	179	181	130	89	121	105	94	495	352	285	66	83	—	49	22·5	43	42·5	36	35	—	31·5	72·6	67·6	71·8	66·8	107·4	79·5	45·9	83·7	82·3	—	87	63	74	43°	13°	30°	87°	cal. old. r. zygomatic defect
7092	[illegible]	1225	187	189	188	130	90	121	103	93	507	375	275	66	88	—	48·5	21	40·5	42	32	33	45	38·5	68·8	64	69·1	64·4	107·4	75	43·3	79	78·6	85·6	93	69°	69	42°	16°	26°	85°	cal. y. ad. l. zygomatic and r. temporal defects. sagittal suture absent, coronal and lambdoid sutures open; hyperdolichocephalic, slight coronal depression
7093	♂	1350	183	181	182	140	91	125	112	94	507	376	302	68·5?	84	115	48	23	42·5	41·5	34	34·5	43	35	77·3	69·1	76·9	68·7	112	81·5	47·9	80	83·1	81·4	85·5	61°	74°	45°	17°·5	27°·5	91°·5	cal. ad.
7094	♂	1605	186	184	185	144	103	132	117	99	529	382	317	77·5	—	138	53·5	22	—	44	—	35	48·5	—	78·3	71·7	77·8	71·3	109	—	41·1	—	79·5	—	93·5	63°	70°	47°	17°	30°	87°	cal. ad. l. malar defect. ossicles in lambdoid suture
7095	♂	1330	187	188	189	138	96	133	111	103	521	377	301	72	90	135	52	23·5	41	40·5	32	32·5	46·5	37	73·4	70·7	73	70·4	103·7	80	45·2	78	80·2	79·6	97	64°·5	73°·5	42°	11°·5	30°·5	85°	cal. ad. (? old). minute ossicles in lambdoid suture. inion well marked
7096	[illegible]	1205	180	179	181	138	91	119	106	95	512	363	292	74	91	—	54	22	41·5	40·5	33·5	34	47	42·5	77·1	66·5	76·2	65·7	116	81·3	40·7	80·7	83·9	90·4	96	68°	66°·5	45°·5	18°·5	27°	85°	cal. ad. l. zygomatic arch broken. ossicle of pterion. tripartite interparietal bone. *torus occipitalis*
7097	[illegible]	1205	170	170	171	136	91	127	110	92	487	353	291	67	82	112	47	22	40	39	32	30·5	45·5	—	80	74·7	79·5	74·3	107·1	81·7	46·8	80	78·2	—	89·5	66°	70°·5	43°·5	15°	28°·5	85°·5	cal. ad. groove of obelion, traces of ossicle of λ. l. ossicle of pterion. slight *torus occipitalis*
7098	♂	1315	184	184	186	130	93	127	108	98	508	366	287	60	85	122	45	24	41·5	43	32	33	48·5	36	70·6	69	69·9	68·3	102·3	70·6	53·3	77·1	76·7	74·2	95	69°	74°·5	36°·5	8°·5	28°	83°	cal. y. ad.
7099	[illegible]	1630	191	190	190	141	92	136	121	99	520	398	319	60·5	71	-	45	22	42	41	33·5	35	42·5	30	74·2	71·6	74·2	71·6	103·7	85·2	48·9	79·8	85·4	70·6	89·5	63°	80°	37°	8°	29°	88°	cal. ad. l. zygomatic defect. ossicles of asterion, r. 18 × 15 mm., l. 11 × 11 mm. inion well developed
7100	[illegible]	1305	183	183	183	136	97	119	109	96	511	356	291	64	86	—	48	23·5	42	42·5	33	33·5	—	—	74·3	65	74·3	65	114·3	74·4	49	78·6	78·8	—	92	67°	73°·5	39°·5	14°·5	25°	88°	cal. ad. (? old) r. zygomatic defect
7101	♂		186	190	189	150	101	137	120	102	540	387	320	70·5	93	135	53	22·5	44	43·5	33·5	34	49·5	34·5	78·9	72·1	79·4	72·5	109·5	75·8	42·4	76·1	78·2	69·7	102	70	70	40	12	25	82	cal. ad. large r. temporal and orbital defect
7102	[illegible]		186	191	192	148	100	134	114	105	534	380	311	—	85	129	50	—	—	39·5	31?	30	48	38?	77·5	70·2	77·1	69·8	110·5	—	—	—	75·9	79·2	96	—	—	—	—	—	89°?	cal. old. frontal and l. facial defects. slight groove of obelion. *torus occipitalis.* ossicles of lambdoid suture
7103	[illegible]		184		185	139	91	131	111 *h*	96	521	385	298	—	—	—	—	—	—	—	—	—	—	—	—	—	75·1	70·8	106·1	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. ad. r. temporal defect. ossicle 20 × 17 mm. in l. lambdoid suture
7104	[illegible]	1450	191	191	191	133	92	130	111	101	518	385	293	75	93	121	53·5	24	41	40·5	32	33·5	51	39·5	69·6	68·1	69·6	68·1	102·3	80·6	44·9	78	82·7	77·4	93	62°	73°	45°	16°	29°	89	cal. ad. (? y. ad.). slight post coronal depression. frontal process of squamous on both sides
7105	♂?	1445	186	186	187	137	102	123	108	102	522	366	292	72·5	86	130	56·5	19·5	45·5	47	39	40	49·5	35·5	73·7	66·1	73·3	65·8	111·3	84·3	34·5	85·7	85·1	71·7	93·5	62°·5	74°·5	43°	13°·5	29°·5	88°	cal. old. r. coronal groove. metopic
7106	[illegible]		180	180	180	134	88	119	107	94		367		57	82		48	23	40?	40?	34?	33?		35?	74·4	66·1	74·4	66·1	112·6	69·5	47·9	85	82·5	—	84?	62°	81°	37°	10°	27°	91°?	cal. senile. l. temporal and occipital defects. slight post coronal depression. r. occipital flattening
7107	[illegible]	1530	182	184	184	138	101	136	120	106	515	369	311	67	94	134	51	27	45	45	32·5	32	53	38·5	75	73·9	75	73·9	101·5	71·3	52·9	72·2	71·1	72·6	105	70°·5	72°·5	37°	8°·5	28°·5	81°	cal. old. traces of ossicle of bregma
7108	[illegible]	1200	181	179	181	133	92	123	107	97	502	351	287	61	88	—	44·5	24	41	42	32·5	33·5	44?	35	74·3	68·7	73·5	68	108·1	69·3	53·9	79·3	79·8	79·5	91	66°	76°·5	37°·5	8°·5	29°	85°	cal. old. r. zygomatic and occipital defects
7109	[illegible]		192		196	145	103	132	113 *h*	104	538	356															74	67·3	109·9	—	—	—	—	—	—	—	—	—	—	—	—	cal. – f. old. extensive temporo-sphenoidal defect. marked bathrocephaly. numerous ossicles of λ and parieto-mastoid sutures. ossicle 12 × 12 mm. in r. coronal. slight *torus occipitalis*
7110	[illegible]		177	178	179	132	95	134	114	101	503	368	308	68	88	121	51	21·5	43	42	33	33·5	47·5	33	74·2	75·3	73·7	74·9	98·5	77·3	42·2	76·7	70·8	69·5	94·5	64°·5	75°	40°·5	11°	29°·5	86°	cal. old l. temporal and r. zygomatic defects
7111		1650	197	192	192	145	97	142	122	102	537	389	321	59·5	94	132	45·5	23·5	42	42·5	30·5	30	43	39	75·5	74	75·5	74	102·1	63·3	51·6	72·6	70·6	90·7	96	67°	78°	35°	8°	27°	86°	cal. ad. healed fracture crossing hinder part l. parietal. faint *torus occipitalis*
7112	♂	1490	186	186	185	142	96	126	111	99	531	374	304	68	96	130	49	23	45	46	30·5	30	50·5	39·5	76·3	67·7	76·8	68·1	112·7	70·8	46·9	67·8	65·2	78·2	101	71°·5	69°	39°·5	14°	25°·5	83°	cal. ad. (? y. ad.). post coronal depression. bulging of temporal portion of coronal suture on either side
7113	[illegible]		184	182	183	134	92	—	107	—	514	372	292	65	82?	—	48·5	25	—	40·5	34	34·5	43	33·5	73·6	—	73·2	—	—	79·3	51·5		85·2	77·9							87°	cal y. ad. large basal and l. malar defects
7114	[illegible]	1355	184	182	184	142	99	126	109	100	525	370	305	69	85	120	53	22	40·5	40	34·5	34	45	—	78	69·2	77·2	68·5	112·7	77·5	41·5	85·2	85	—	93·5	64°	74°	42°	12°	30°	86°	cal. ad. metopic. faint depression of obelion
7115	[illegible]	1045	164	162	163	126	90	116	99	88	465	334	260	55·5	86	116	42	20·5	38	37·5	31	31	40·5	31	77·8	71·6	77·3	71·2	108·6	64·5	48·8	81·6	82·7	76·5	81·5	64°·5	77°·5	38°	7°·5	30°·5	85°	cal. ad.
7116	[illegible]		170	171	171	136	94	127	110	98	489	350	290	66	86	—	46	24	39·5	40	31·5	30	46	35·5	79·5	74·3	79·5	74·3	107·1	76·7	52·2	79·7	75	77·2	97	69°	71°	40°	10°	30°	81°	cal. ad. l. temporal defect. metopic. post coronal depression. small r. ossicle of pterion and small ossicles in lambdoid suture
7117	♂	1630	201	203	203	143	97	133	120	100	556	407	320	76·5	92	—	57·5	28	43	44	36·5	35·5	53·5	?	70·4	65·5	70·4	65·5	107·5	83·1	48·7	84·9	80·7	—	100·5	68°	67°	45°	18°	27°	85°	cal. ad. l. zygoma defective
7118	♂		186	185	184	143	97	132	113	104	515?	363?	302	59	99?	138	46·5	27	43·5	43	34	33	47	35	77·3	71·3	77·7	71·7	108·3	59·6	58·1	78·2	76·7	74·5	97	66°·5	79°·5	34°	—	—	—	cal. old. occipito-parietal defect
7119	♂	1570	196	197	196	148	105	137	123	98	558	410	342	73·5	91	131	51·5	25	44	43·5	38	36	48	27·5	75·1	69·5	75·5	69·9	108	80·8	48·5	86·4	82·8	57·3	96·5	66°·5	69	44°·5	14	30°·5	83	cal. ad
7120	♀	1345	188	190	191	135	96	126	103	99	515	376	275	62	95		45·5	22·5	42·5	43	34·5	35	42·5	30	71	66·3	70·7	66	107·2	65·3	49·4	81·2	81·4	84·7	89	62°	80°	38°	6°	32°	86°	cal. old. defective l. zygoma. edentulous save for retained r. canine. post coronal constriction. *torus occipitalis*

7062 7088: there are no skulls with these numbers in this series.

MEASUREMENTS OF

TABLE VIII.

Face							Remarks
		O_1		O_2			
NH	*NB*	*L*	*R*	*L*	*R*		
47·5	24	43	43·5	32	31·5	4	trongly marked inion
54	25·5	39·5	40	33·5	33	4	r. parietal defect. slight *torus occipitalis*
50·5	23·5	—	44·5	33	32·5	4	rge r. occipital and l. malar defects. healed d fracture in l. parietal. ossicles in lamb- ure
52·5	—	43	—	33	—	5	side of face very defective. plagiocephalic. tal and l. frontal flattening. inion prominent
52	—	43·5	—	31·5	—		. half of face wanting
50	23	42	41·5	31	32·5	4	. zygomatic defect. ossicles in lambdoid rather prominent inion
49	27	45	—	35	36	5	large r. temporal defect and transverse of base. traces of transverse occipital

es .	*W*₁	*W*₂	*h*₁	*f*
	119	96	—	47·5
	112·5	90	27·5	43
	120	87·5	29	45·5
	—	—	39·5	43
	126	94	34·5?	42·5
‡	85	76·5	24·5	35·5
	108	84	28	42
	110·5	104	32	44
	104	80·5	24·5	43·5
	120?	97	34	43
	—	—	39·5	48·5
	112	93	31·5	43
	—	—	24·5	41
	—	92	33·5?	41
	—	108·5	30?	45
	119·5	108·5	—	45·5
	104?	87	—	44·5
	111·5	90·5	—	42
	118	92?	—	46·5
	120	90·5?	31·5	45
	—	96·5?	30	45
	108?	98·5	29	45·5
	118	100·5	32	45
	114·5	85	27·5	45·5
	113?	90·5	34·5	40
	113	109·5	30?	50
	112·5	99·5	28·5	44
	110	98	30?	42·5
	109	86·5	—	43
	—	—	31·5	45
	118·5	91·5	31·5	41
	123·5	100	30·5	43
	117	—	26	46·5
	112	100·5	36	42·5
	107·5	92	32·5	43·5
	109?	81·5	26?	40·5

ere unfortunately not kept with their particu

† *foramen mentale* double on left.

MEASUREMENTS OF SEVENTEENTH CENTURY ENGLISH CRANIA.

TABLE VIII

Series No.	Sex	C	Lengths L'	L	L	B	B'	H	OH	LB	Circumferences U	S	Q	Face $G'H$	GB	J	NH	NB	O_1 L	O_1 R	O_2 L	O_2 R	Palate G_1	G_2	Indices B/L'	H/L'	B/L	H/L	B/H	$G'H/GB$	NB/NH	O_2/O_1 L	O_2/O_1 R	G_2/G_1	GL	Angles $N\angle$	$A\angle$	$B\angle$	θ_1	θ_2	$P\angle$	Remarks
7121	♂	1575	193	193	193	144	97	136	116	101	534	395	315	63	86	128	47·5	24	43	43·5	32	31·5	44	38	74·6	70·5	74·6	70·5	105·9	73·3	50·5	74·4	72·4	86·4	90	61	81	38	9	29	90	cal. ad. strongly marked inion
7122	♂		189	193	193	141	94	131	119	103	533	390	320	70	87	123	54	25·5	39·5	40	33·5	33	45	40	73·1	67·9	73·1	67·9	107·6	80·5	47·2	84·8	82·5	88·9	90	59	79	42	17	25	96	cal. old. r. parietal defect. slight *torus occipitalis*
7123	♂		197	197	198	145	100	138	117	96	545	–	316	71	98	123	50·5	23·5		44·5	33	32·5	49	38·5	73·6	70	73·2	69·7	105	72·4	46·5		73	78·6	89?	62·5	73	44·5	11	33·5	84?	cal. ad. large r. occipital and l. malar defects. healed depressed fracture in l. parietal. ossicles in lambdoid suture
7124	♂	1375	183	188	180	141	99	129	112	102	515	360	300	69			52·5		43		33		55		75	68·6	74·6	68·2	109·3			76·7			99	67°·5	72°·5	40°	11°·5	28°·5	84°	cal. ad. r. side of face very defective. plagiocephalic. r. occipital and l. frontal flattening. inion prominent
7125	♀	1335	179	177	179	138	94	129	113	98	507	361	303				52		43·5		31·5			-	78	72·9	77·1	72·1	106·9			72·4										cal. ad. r. half of face wanting
7126	♀	1255	181	183	183	134	92	124	102	102	501	349	281	66·5	89	127	50	23	42	41·5	31	32·5	47·5	36·5	73·2	67·8	73·2	67·8	108·1	74·7	46	73·8	78·3	76·8	96	65·5	75·5	39	8·5	30·5	84	cal. ad. l. zygomatic defect. ossicles in lambdoid suture. rather prominent inion
7127			196	196	197	—	100	137	119	—	—	388	—	68	88	—	49	27	45	—	35	36	50·5	36	--	69·9	—	69·5	—	77·3	55·1	77·8	—	71·3		—	—	—	—	—	86°	cal. ad. large r. temporal, defect and transverse fracture of base. traces of transverse occipital suture

MANDIBLES*.

Series No.	W_1	W_2	h_1	f
1	111	87	—	46·5
2	109	94	27·5	44
3	—	—	33	47
4	115	104·5	29·5	41
5	—	117	35·5	47
6	123	105	37·5	46·5
7	—	—	34·5	39·5
8	110	102	28?	43
9	—	85	33·5?	39·5
10	106	86·5	30	48
11	—	95·5	30·5	44
12	127	105	—	45
13	—	—	29?	47
14	—	—	30	44
15	114	97	28	41
16	124	98	33·5	48
17	107	95·5	27·5	40·5
18	—	—	33?	48
19	—	90	29	41·5
20	102·5?	87	30	41·5
21	108	92·5	31	42·5
22	111	91	28	41
23	115·5	109	25·5	45 44 †
24	121·5	98	31·5	44·5
25	103·5	89	35·5	42
26	—	89	25·5	44
27	123	105·5	31	42
28	111·5	97	24·5	46·5
29	113·5	94	36	40·5
30	118	89·5	31·5	45·5
31	—	88·5	31?	40
32‡	97·5	77·5	23?	40·5
33	—	97	—	41
34	111	99	35	41·5
35	115	91	—	43·3
36	119	96	—	47·5
37	112·5	90	27·5	43
38	120	87·5	29	45·5
39	—	—	39·5	43
40	126	94	34·5?	42·5
41‡	85	76·5	24·5	35·5
42	108	84	28	42
43	110·5	104	32	44
44	104	80·5	24·5	43·5
45	120?	97	34	43
46	—	—	39·5	48·5
47	112	93	31·5	43
48	—	—	24·5	41
49	—	92	33·5?	41
50	—	108·5	30?	45
51	119·5	108·5	—	45·5
52	104?	87	—	44·5
53	111·5	90·5	—	42
54	118	92?	—	46·5
55	120	90·5?	31·5	45
56	—	96·5?	30	45
57	108?	98·5	29	45·5
58	118	100·5	32	45
59	114·5	85	27·5	45·5
60	113?	90·5	34·5	40
61	113	109·5	30?	50
62	112·5	99·5	28·5	44
63	110	98	30?	42·5
64	109	86·5	—	43
65	—	—	31·5	45
66	118·5	91·5	31·5	41
67	123·5	100	30·5	43
68	117	—	26	46·5
69	112	100·5	36	42·5
70	107·5	92	32·5	43·5
71	109?	81·5	26?	40·5
72	—	89?	—	42·5
73	115	91	30·5	44·5
74	—	90·5	—	38·5
75	112·5	108·5	—	46
76	111·5	93	27·5	46·5
77	114	91·5	29·5	45
78	—	105	39	45·5
79	119·5	85	31?	41·5
80	112	99·5	35	44
81	114·5	95	27	35
82	105·5	91	30·5	44
83	121	99·5	32·5	45
84	—	85	27·5?	40
85	—	—	30	46
86	—	—	31	43·5
87	104·5	90	36	41·5
88	114·5	90·5	32·5	46·5
89	—	96·5	—	46·5
90	116	97	35	42
91	—	111·5	—	48·5
92§	81	68	20	34·5
93	113	104?	—	49
94	—	95·5	30	39·5
95	106·5	92	29	43
96	—	103	35	47
97	119	95	—	43·5
98	108·5	97	—	44
99	121·5	116	32	45
100	111	83	29	44·5
101	—	113	31	43
102	—	95	—	46
103§	—	70	21·5	36·5
104	109	88	24	41·5
105	111·5	89·5	29	44
106	114·5	95·5?	33	43·5
107	119·5	88·5	29·5	46
108	118	—	34·5?	45
109	—	95·5	33	44·5
110	119·5	99·5	32·5?	41
111	—	106·5	27·5	50
112	—	104?	—	46·5
113	—	93?	33·5	43
114	119·5	97	32	43
115	—	—	30	45·5
116	—	—	—	42
117§	—	—	—	37
118	—	85·5?	—	41·5
119	106·5?	86	22·5	43·5
120	—	90	25	43
121	—	111·5	32	48
122	—	114	—	49·5
123	119·5	90	—	42·5
124	—	—	32·5	42
125	116	101·5	32·5	45·5
126	—	110	—	43·5
127	101?	81·5?	27·5	39·5
128	119	89	26	47
129	105·5	85·5	—	42·5
130	118·5	102·5?	30	45·5
131	105·5	88	27?	42·5
132	102·5?	87?	33	41
133	—	90·5	34·5	39
134	96·5?	82	24·5	39
135	126	117	—	50
136	110	85·5	—	42·5
137	105·5	94	29	43·5
138	102·5	99·5	30?	41·5
139	105·5	92	24·5	41
140	114·5	97·5	—	41·5
141	113	90·5	—	41·5
142	—	101	32?	44·5
143	—	85	—	43
144	112	97		44
145	118·5	98		43·5
146‡	103·5	85·5	29	40·5
147		112·5	34	40·5
148	115	82	31·5	39·5
149		90	22·5	41
150	120	102·5		47
151		88	27	40
152		73·5	23·5	35
153	113·5	90·5		44
154	107	80·5	27	40
155		95	35	40·5
156			34	44
157	110	89	28?	41
158		108		45·5
159	113·5	90	30	40
160	109	90	35	40·5
161	120	98	31	45
162	102	86	28·5	41
163	110	96	31·5	43·5
164	—		29·5	41·5
165	116	102	34·5	48·5
166‡	91	87	23	40
167	—	92?	25?	47
168	112	96	34·5	43·5
169		—	–	45·5
170		106·5	33·5	46·5
171		103·5	35·5	45
172	—	92?		44
173	107?	87	30	42·5
174		107·5	31·5	45
175		102	35·5	45
176			24	37·5
177		117	37·5	48·5
178	130	94·5	38	43·5

* These mandibles, when the bones were dug up, were unfortunately not kept with their particular crania and as it has not been found possible to satisfactorily sex the great bulk of them, no statement as to sex has been made.

† *foramen mentale* double on left.

‡ Young adult.

§ Infantile.

ON INHERITANCE OF COAT-COLOUR IN THE GREYHOUND.

By AMY BARRINGTON, ALICE LEE, and KARL PEARSON.

(1) *Introductory.* There is little doubt that if money and time were no consideration direct experiments on the breeding of dogs would lead to results of the highest importance not only for the theory of inheritance, but also for the practical guidance of dog-fanciers. To be of the most complete service such experiments would have to commence with two or three generations of in-breeding simply to insure the purity of the various stocks to be employed in the final experiments*. Further, in the description of the selected characters, a classification would have to be adopted of a far more comprehensive character than appears to be usual in a number of recent experiments on hybridisation. Lastly, from the standpoint which we believe to be the correct one, that safe conclusions can only be drawn from the average of large numbers of crossings, at least 50 and probably 100 individuals of both sexes would have to be the basis of an effective experimental stud†. Now the difficulty both in time and money of dealing with such a stud may not in the future be insuperable, but at present to propose it as the only means of approaching the problem of inheritance in dogs is to adjourn *sine die* any consideration of that problem. In certain points also the extensive breeding records which are already available for dogs possess advantages which are not to be wholly disregarded when we compare them with the special merits of a biometric stud-farm. In the first place we have all the gain which arises from dealing with literally immense numbers. For example, in the present memoir we were able to classify over 10,000 cases of parent and

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* For example when this is wanting, we find as in the case of some recent experiments on rabbits, inconclusive results reached, because the judgment of purity is based on *a posteriori* examination of the experimental litter, judgment which might be, and actually was in certain cases, reversed on the appearance of a second litter from the same pair.

† 10 offspring of each of 50 hybridisations give an incomparably more valuable result than the 100 offspring of one or two hybridisations to which we are frequently treated.

offspring, over 7000 cases of grandparent and offspring, and over 24,000 cases of siblings. Nothing approaching such totals could be obtained by experiment *ad hoc*. Further, the colour pedigrees for a number of generations were directly available. Against these advantages is to be put in the foremost place the primary value of exactitude and uniformity in record such as might be obtained in a well organised scientific experiment. This counts for a great deal, but it does not count for everything with those who realise what are the probable errors of small series, and how inconclusive such series usually are*. On the other hand also, if we admit the want of scientific exactness and the play of individual judgment in the character classifications of breeders, we have still to remember that when the breeding of a particular species has been long established a conventional scale also grows up which, owing to the contact of breeder with breeder at sales and shows, and further to the regulations of societies and judges, becomes within broad lines universally recognised and appreciated. Hence, while we fully recognise all the disadvantages of stud-book records, we still hold that highly valuable work may be done in the field of inheritance by accepting the classification of professional, if non-scientific breeders.

So far as we are aware no series of dogs has been dealt with or at least any results for such a series published since Mr Francis Galton's work on Basset Hounds†. We have long felt that that work needed supplementing, partly because it dealt with a rather small group of much inbred hounds, and partly because, especially in the matter of paternal inheritance, it presented irregularities, which even raised a suspicion of the goodness of the record‡. The greyhound naturally occurred to us as a dog of old standing bred for a purpose—speed—which was not closely and obviously associated with its coat-colour. We were, however, warned that breeders for coursing did fancy certain colours, and we found that the record as presented by the greyhound stud-books was very incomplete, i.e. a very small proportion of the members of any litter were ever recorded in these volumes. Hence, if selection for record took place largely by colour, we might be misled by the greyhound stud-book in a manner impossible in the case of the stud-book for thoroughbred race-horses. An examination of other dog records left on our minds the same doubt as to possible colour-selection in other cases, and thus, although the inheritance of coat-colour in dogs had been proposed for treatment at the same time as the race-horses were dealt with in 1899§, we had felt bound to leave it untouched. Meanwhile Mr Howard Collins of Edgebaston had also been occupied with the same problem, and troubled with the same doubt. He surmounted the difficulty, however, by the issue to greyhound breeders of a very large number of schedules in which details of colour of sire, dam, and the *whole* of the resulting litter were to be entered. In response to his request a large number of these schedules were duly filled in. All this material he placed unreservedly at the disposal of Professor W. F. R. Weldon, who in his turn handed it over for classification and calculation to the biometric workers in University College, London. This splendid material, for which we cannot too heartily thank Mr Collins and Professor Weldon, was supplemented by additional data extracted from the volumes of the *Greyhound Stud-book*[*]. Thus the four fundamental parental tables were drawn from Mr Collins' data; four other parental tables for purposes of comparison and control were based on the stud-books. All the eight fundamental grandparental tables were based on pedigrees compiled from the stud-books, for Mr Collins' data extended to one generation only. Of the nine fundamental sibling tables, three for siblings from the same litter are based on Mr Collins' data, three for siblings from different litters and three for siblings of the same litter on the stud-books. The extraction of pedigrees from the stud-books and the classification of all the data into tables is the work of A. Barrington[†]. In the calculation of the correlations, the whole of the 50 sets taken by the fourfold table method are due to A. Lee. The whole of the calculation of correlations by the mean square contingency method was undertaken by A. Lee and A. Barrington conjointly. The labour of classification and calculation has been the work of a good many months, and has been more strenuous than is, perhaps, apparent on the surface. Only the work of putting the numerical results into tabular form and drawing conclusions from them is due to the third joint author of this paper.

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* We have here in another form the great advantage, amid many disadvantages, of anthropometry as compared with craniometry.

† *R. S. Proc.* Vol. 61, p. 403.

‡ Pearson: "On the Law of Reversion." *R. S. Proc.* Vol. 66, p. 159.

§ Pearson and Bramley-Moore: *Phil. Trans.* Vol. 195, A, pp. 79—150.

(2) *Nature of colour classifications used.* In the classification of the greyhound we find in the first place the following main colours: *Red* (R.), *Fawn* (F.), *White* (W.), *Brindle* (Bd.), *Blue* (Be.), *Black* (Bk.). Besides these main colours we have a series of doubtful intermediates such as *Red or Fawn* (R. or F.), *Fawn or Red* (F. or R.), and a wide range of mixtures or particoloured dogs. Such are *Red-White* and *White-Red* (R. W. and W. R.), mixtures of Red, Fawn and White, e.g. R. F., F. R., W. F., F. W., R. F. W., F. R. W., W. R. F., R. or F. W., W. F. or R., W. R. or F., and the mixed brindles chiefly W. Bd., or Bd. W., but also: F. Bd., Bd. F., R. Bd., Bd. R., R. Bd. W., Be. Bd., Be. Bd. W., W. Bd. Be. Lastly we have the *Mixed Blues* and *Mixed Blacks*, including the *Ticked* (Tk.), e.g. Bk. W., W. Bk., Bk. Tk., Bk. W. Tk., W. Bk. Tk., W. Tk., Be. Tk., Be. F., Be. W., W. Be. In all we have found nearly forty different colour classes. Some of these of course are very similar, others perhaps not so definite as might be desirable; but the bulk of the cases fall into fairly well-defined groups, and the isolated units while they are recorded for future use in our fundamental tables have been embraced in wider groupings in the more manageable tables from which our numerical results are drawn.

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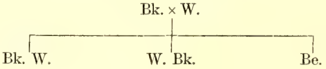
[*] At present twenty volumes have appeared. The Editor is Mr W. F. Lamonby and it is published at the "Field" Newspaper Office.

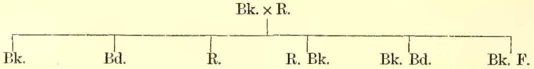
[†] Actually she prepared 25 out of the 26 fundamental tables; the remaining table was originally prepared by F. E. Lutz, but it was revised and modified when the other series were extracted.

According to some authorities black and red are the original greyhound colours; white is said not to be found in any "natural breed of dogs." Black, red and white are often looked upon, however, as the three primitive "colours" by breeders. A mixture of these colours may then lead to a blend as in "fawn" and "blue," to particolour in large patches, to ticking in small spots or to stripes. According to Stonehenge we have the following pedigrees:

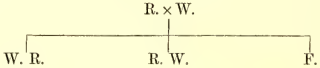
(*a*)



(*b*)



(*c*)



We are not convinced that such results pay sufficient attention to ancestry beyond the parents. Bd. × Bd. breeds as large a proportion true to parents as R. × R. or Bk. × Bk. Bk. × Bk. can produce R. and also F. The accompanying tables give the distribution of parents in the case of 2384 dogs and 2200 bitches. Here, to keep the tables within manageable limits, white has not been treated as a separate group except in the case of pure whites. Thus, of the red sires between $\frac{1}{3}$ and $\frac{1}{4}$ are red and white; of the brindle sires between $\frac{1}{2}$ and $\frac{1}{3}$ are brindle and white; of the fawn sires more than $\frac{1}{2}$ are fawn and white; of the mixed black sires $\frac{5}{7}$ are black and white and about $\frac{1}{7}$ blue; the remaining $\frac{1}{7}$ being chiefly blue and white, with a sprinkling of ticked and other rather nondescript dogs. Red shades off into fawn so that quite a large class of sires between $\frac{1}{6}$ to $\frac{1}{7}$ of the reds are described as red or fawn. Besides these we find a few isolated units classed as red and fawn, or red, fawn and white. As the tables stand, pure black contains dogs without mixture of red, fawn, brindle or white; fawn contains fawn, white and fawn; red contains red, red-fawn, red or fawn, and these with white. Brindle contains brindle, brindle-white with a few isolated units of brindle-reds and brindle-fawns. The blue-brindle and brindle-blacks are included in the mixed blacks. For more detailed classifications the reader must refer to the complete tables in the Appendix of this memoir. Now a reference to the above tables will show that melanism may appear in R. × R. crosses as well as in F. × F. crosses; that Bd. × Bd. may produce pure white or pure black dogs; that Bk. × R. may give white dogs; and that pure black dogs may produce pure white, red or fawn dogs. To use Mendelian language, the whole race of greyhounds appears to be in a heterozygous condition, and such pedigrees as those we have quoted from Stonehenge appear to have little valency when large numbers are studied.

(3) *White Dogs.* One great defect in our data is made manifest by an examination of Tables I and II; although we have there the parents of 4584 dogs

TABLE I.

Offspring Dogs.

Sires.

Dams.		Red	Brindle	White	Fawn	Pure Black	Mixed Black	Totals
Red	Red	37	10	—	52	19	17	135
	Brindle ...	4	40	—	—	7	7	58
	White ...	1	—	3	—	—	2	6
	Fawn ...	4	6	—	22	14	12	58
	Pure Black...	1	2	—	—	31	33	67
	Mixed Black	1	3	—	—	19	43	66
Totals	—	48	61	3	74	90	114	390
Brindle	Red	19	5	—	13	—	8	45
	Brindle ...	51	81	3	31	15	25	206
	White ...	2	1	—	1	—	—	4
	Fawn ...	16	8	1	20	1	10	56
	Pure Black...	—	—	—	—	28	23	51
	Mixed Black	1	1	—	2	5	53	62
Totals	—	89	96	4	67	49	119	424
White	Red	—	—	—	1	—	—	1
	Brindle ...	—	—	—	3	2	5	10
	White ...	—	—	—	2	—	1	3
	Fawn ...	—	—	—	5	—	2	7
	Pure Black...	—	—	—	—	—	3	3
	Mixed Black	—	—	—	2	5	10	17
Totals	—	—	—	—	13	7	21	41
Fawn	Red	16	10	—	14	13	5	58
	Brindle ...	—	39	—	—	7	10	56
	White ...	1	2	1	—	1	—	5
	Fawn ...	17	26	1	14	20	35	113
	Pure Black...	—	2	—	—	26	29	57
	Mixed Black	3	5	—	10	7	88	113
Totals	—	37	84	2	38	74	167	402
Pure Black	Red	15	8	—	5	9	5	42
	Brindle ...	8	33	—	7	10	12	70
	White ...	—	—	—	—	—	2	2
	Fawn ...	4	3	—	15	7	3	32
	Pure Black...	49	41	—	22	90	54	256
	Mixed Black	8	16	—	20	27	48	119
Totals	—	84	101	—	69	143	124	521
Mixed Black	Red	23	2	—	11	4	5	45
	Brindle ...	17	30	—	9	1	9	66
	White ...	3	—	—	7	1	3	14
	Fawn ...	7	18	—	44	9	10	88
	Pure Black...	16	14	—	13	25	38	106
	Mixed Black	28	58	—	53	33	115	287
Totals	—	94	122	—	137	73	180	606
Grand Totals	—	352	464	9	398	436	725	2384

TABLE II.

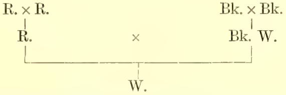
Offspring Bitches.

Sires.

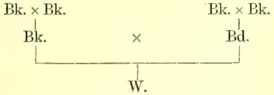
Dams.

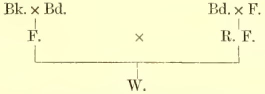
		Red	Brindle	White	Fawn	Pure Black	Mixed Black	Totals
Red	Red	43	10	—	52	18	15	138
	Brindle ...	2	55	—	—	9	10	76
	White ...	—	—	3	—	1	1	5
	Fawn ...	9	8	—	19	11	15	62
	Pure Black ...	—	1	—	—	29	29	59
	Mixed Black	—	1	—	—	18	39	58
Totals	—	54	75	3	71	86	109	398
Brindle	Red	22	9	—	4	—	5	40
	Brindle ...	36	76	2	22	9	23	168
	White ...	1	2	—	1	—	2	6
	Fawn ...	8	5	1	25	—	9	48
	Pure Black ...	5	—	—	—	26	16	47
	Mixed Black	1	—	—	2	3	60	66
Totals	—	73	92	3	54	38	115	375
White	Red	—	—	—	2	—	—	2
	Brindle ...	—	—	—	—	1	4	5
	White ...	—	—	—	3	—	2	5
	Fawn ...	—	—	—	10	—	—	10
	Pure Black ...	—	—	—	—	—	—	—
	Mixed Black	—	1	—	2	2	12	17
Totals	—	—	1	—	17	3	18	39
Fawn	Red	7	12	—	13	9	4	45
	Brindle ...	—	30	—	—	6	11	47
	White ...	—	1	—	1	2	—	4
	Fawn ...	17	21	4	17	14	20	93
	Pure Black ...	—	2	—	—	27	23	52
	Mixed Black	1	6	—	7	13	70	97
Totals	—	25	72	4	38	71	128	338
Pure Black	Red	22	4	—	4	4	4	38
	Brindle ...	4	29	—	7	9	10	59
	White ...	1	—	—	—	—	—	1
	Fawn ...	10	7	—	23	4	5	49
	Pure Black ...	27	27	—	26	89	74	243
	Mixed Black	8	16	—	7	20	43	94
Totals	—	72	83	—	67	126	136	484
Mixed Black	Red	16	6	—	7	3	2	34
	Brindle ...	17	35	—	11	7	12	82
	White ...	2	1	—	3	—	2	8
	Fawn ...	6	13	—	43	8	3	73
	Pure Black ...	18	16	—	11	26	23	94
	Mixed Black	27	43	—	58	29	118	275
Totals	—	86	114	—	133	73	160	566
Grand Totals	—	310	437	10	380	397	666	2200.

and elsewhere the parents of at least 4000 others, in no case have we the cross W. × W. This is undoubtedly an important cross and we endeavoured to obtain data on this point by seeking out the pedigrees of all the white dogs whose names were known to us. The paucity of material is due to the fact that very rarely one of a litter is pure white, and we have no evidence of any attempt to breed persistently from W. × W.* Upwards of 50 pedigrees of 'white' dogs going back to their 16 great-great-grandparents, and in some cases their great-great-great-grandparents were drawn up with the colours added in all cases where we could ascertain them. But not very definite information could be extracted from these pedigrees. There were six cases only of a W. dog with one parent W., three white dams and three white sires. Of these six cases of W. from parent W. we had no case of the parents of the W. parent being recorded as white. Indeed, no case of a W. grandparent at all. One or other of the grandparents was usually particoloured white. There were 16 cases in which a white dog was recorded from parents *both* of whom were white particolour. In all these cases there was white particolour in the grandparents in one or more cases, but quite frequently neither parent of a particoloured parent had any white; for example, R. × Bd. frequently gave white particolour. In only one recorded case was there a W. grandparent in this series. Where the grandparents of the W. dog through a particoloured white parent were R. × Bd. we found the white particolour reappeared in the parents of one or other or both of the R. and Bd. grandparents. There were 16 cases of one particolour white parent to the W. dog. In all these cases except one, there was more or less particolour white in the grandparents. In this one case we have:



But at least three of the great-grandparents, partly on the red and partly on the black side, were white particolour. There were 19 cases of white dogs with no white recorded at all in their parents, but here again the particoloured white appeared almost always in the grandparents. Of the two exceptions the pedigrees are;





But in both cases the particolour white occurs in the great-grandparents.

Of the 18 W. dogs with no recorded white in the parentage, four were from Bk. × R. crosses, one from a Bk. × Bk. cross, and six from Bd. × Bk. crosses.

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* Mr W. F. Lamonby informs us that no breeder has made a speciality of a pure white strain; and considers that the attempt to create it would fail as the colours of former generations would crop up. This shows at any rate that leading breeders' opinion does not believe in white breeding true.

Further, four were from R. × F. crosses, and the remaining five introduced Be., Bk., Bd. and F. crosses of a miscellaneous character.

It is obvious from these results that the breeding out of white would be at least a difficult task, and that when white has substantially disappeared for a couple of generations, it may suddenly reappear in full force. If it be suggested that Bk. in the nomenclature would not exclude a white toe, nor W. a small black spot, then the reply must necessarily be that no theory of heredity can be of service for the purposes of evolution which would make one class of a white dog with a black toe and a black dog with a few white hairs on the throat, and professes only to predict when such a class as a whole will occur. The protective value of the coat-colour in the two cases would be wholly and entirely different, and we should have to seek further for those features of the pedigree with which the differentiation could be associated.

(4) *Colour Scales and Reduction Methods.* When we first started work on the greyhounds, the method of contingency had not yet been developed, and accordingly we made tables for the inheritance of melanism and of red pigment and proceeded to find the correlations by the fourfold division process*. In our classification we must admit having been influenced by the statement of breeders that brindle is the result of the crossing of red with black. A glance at our Tables I and II will show, however, that we cannot look upon red and black as pure forms giving a heterozygous brindle. We have in percentages based on 332

R. × Bk.

R.	Bd.	W.	F.	P. Bk.	M. Bk.
22 %	8 %	1 %	12 %	41 %	16 %

cases: a result which is capable of interpretation when we pay attention to ancestry (or, again, on the basis of a mixture of alternative inheritance and reversion), but is scarcely reducible to any simple Mendelian proportions, still less is it compatible with R. × Bk. = Bd.

The fact that R. × R. or R. × F. very rarely gives black of any kind (although F. × F. can give black), while Bd. × Bd. in the rarest cases gives Bk. of any kind, seems to denote more red than black in ordinary brindle and a closer relation of brindle to red than of fawn to red, although F. × F. in the bulk gives equal amounts of red and fawn. Accordingly we grouped our classes for red and black pigments as follows:

Red Pigment

(*a*) Red.
(*b*) Brindle.
(*c*) Fawn.
(*d*) No Red.

Black Pigment

(*a′*) Pure Black.
(*b′*) Mixed Black.
(*c′*) Brindle.
(*d′*) Fawn.
(*e′*) No Black.

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* *Phil. Trans.* Vol. 195, A, pp. 1—47.

(*d*) contained all dogs with white or black, but no red or fawn of any kind. (*e*′) contained all red or white dogs or the mixture of these colours with fawn. We are now not at all certain that (*d*′) does not really contain more of black than (*c*′). We worked out afresh a certain number of tables in which (*d*′) was placed before (*c*′) but without real modification of result. The fourfold division of the red pigment inheritance table was made between (*b*) and (*c*), and of the black pigment table between (*c*′) and (*d*′) for the first set of cases, and after (*b*′) when (*d*′) was placed above (*c*′). We shall cite these methods as *Red A*, *Black B* and *Black C*, respectively. In contingency we took a 36-fold table as our standard, choosing the groupings R., Bd., W., F., P. Bk. and M. Bk. used as in Tables I and II. We shall speak of this method as *Contingency D*. In order to compare the fourfold method with contingency methods, 16-fold tables and 25-fold tables were worked out to compare with the fourfold tables adopted for the inheritance of red and black pigment respectively. These we shall refer to as *Contingency E*, and *Contingency F*. Further, in order to familiarise ourselves thoroughly with the scope and limitations of the new method of contingency, beside the investigations by mean square contingency adopted in D, E, F, we (*a*) determined a number of results by mean contingency*; and (*b*) worked out the mean square contingency in a few cases by 144-fold and 400-fold tables. The object of the latter was to test on a large scale the exaggerating effect of isolated units. The amount of arithmetical calculation involved in this investigation is thus not at all represented in the pages of the present memoir, but we believe it has been of advantage in enabling us to form just appreciations of the scope of the new method of contingency. In future it is likely that all our work on colour inheritance will be done by the use of method D, i.e. the application of mean squared contingency to groups sufficiently large not to be sensibly influenced by unit difficulties. Even with our 36-fold table the smallness of the white entries is to some extent a difficulty, but the Contingency F method shows us that the separation of the small unit groups of white has not seriously modified our results. The results deduced by Contingency D method are singularly uniform and steady as compared with those of the fourfold-table methods, and we believe if it be adopted generally for such pigmentation problems, it will not only free us from any question of pigmentation scale, but afford a good result on a not excessive expenditure of calculating energy. At the same time we can hardly over-emphasise the need for caution when isolated units are scattered over a table divided into a very large number of small classes†. As illustration of this we cite the following results for the correlation between siblings—dog and bitch—born in different litters of the same parents.

It will be seen that while the contingency result only increases from ·49 to ·51 when we pass from 16 to 36 groups, agreeing well with fourfold table results, we spring up to ·76 as we increase to 400 groups. In fact, the personal equation of any breeder who may call his dogs 'red-fawn' when the majority of breeders would call them 'red' is sufficient to very seriously alter the results when only 2000 dogs are dealt with. Accordingly, our choice of 16 to 36-fold classifications is based on the experience that these give results substantially in agreement with totally different methods, and we take as our standard process the mean square contingency method referred to above as D.

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* *Draper's Research Memoirs I.* "Mathematical Contributions to the Theory of Evolution: XIII. On the Mathematical Theory of Contingency," p. 31 (Dulau and Co., Soho Square, London).

† Memoir on contingency, *loc. cit.* pp. 16 and 35.

TABLE III.

Correlation of Brothers and Sisters from Different Litters.

Mean of fourfold Tables (A and B)	·521
16-fold Contingency Table E	·488
25-fold Contingency Table F	·502
36-fold Contingency Table D	·509
144-fold Contingency Table	·640
400-fold Contingency Table	·760

Lastly, in case the reader should enquire why we dealt with red pigmentation and black pigmentation and have not considered the inheritance of white, we must remark that while many of the breeders filling in Mr Howard Collins' papers have noted a white ear or small white patches, etc. on black dogs*, we believe possibly the majority, it is not certain that absolutely all have done this; and we are quite sure that insignificant white patches are not noted in the stud-books. Accordingly it seemed best to confine our attention solely to the inheritance of black and red pigment. At the same time we make no statement as to our belief whether or no these pigments are qualitatively different; we consider that the contingency method enables us to fairly escape any such decision. No satisfactory treatment of the nature of pigment in hair has so far come to our notice.

(5) *On Direct Inheritance. Parental Correlations.* We place here our results for the data extracted from Mr Howard Collins' schedules and from the stud-books in the case of the four parental correlations worked out by method *Contingency D.*

TABLE IV.

	Unselected Offspring		Offspring Selected for Record		
	Number	Correlation	Number	Correlation	
				Raw	Corrected
Sire and Dog ...	2392	·512	963	·474	·542
Sire and Bitch ...	2231	·579	913	·404	·462
Dam and Dog ...	2419	·505	963	·485	·554
Dam and Bitch ...	2237	·532	913	·499	·572
Mean ...	—	·532	—	·466	·532

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* Such dogs have been classed as 'mixed black.'

The mean of 12 fourfold tables, three for each parental table, by methods of division A, B, C above, was ·526. We think we may therefore safely say that the 36-fold contingency table leads to results in quite good agreement with the mean of the older process of dealing with quantities not quantitatively measurable. Nor are the individual results which by the fourfold method are: Sire and Dog, ·538; Sire and Bitch, ·615; Dam and Dog, ·467; Dam and Bitch, ·482, widely different. Nor do we find any sensible difference if we consider the inheritance of 'red pigment' and of 'black pigment,' the mean parental coefficients being ·520 and ·529 for the two cases respectively. Lastly, the mean parental correlation from four 25-fold and four 16-fold contingency tables was ·492, somewhat less than the value as given by the fourfold method or the 36-fold contingency method, which, as we have seen, are in good agreement. We believe that ·53 represents extremely well the average parental relation in pigment in the case of greyhounds.

We compare this in the following table with previous pigmentation results:

TABLE V.

Direct Inheritance of Pigmentation.

	Man Eye-Colour	Horse Coat-Colour	Dog, Basset Hound Coat-Colour	Dog, Greyhound Coat-Colour	Mean
Father and Son ...	·550	·491	?*	·512	·518
Father and Daughter	·437	·542	?	·579	·519
Mother and Son ...	·482	·486	·508	·505	·495
Mother and Daughter	·510	·567	·544	·532	·538
Mean ...	·495	·522	·526	·532	·518

This table seems to indicate that there is no evidence at present to show that pigmentation inheritance differs in intensity in man, horse or dog, nor is there evidence to indicate any persistent preponderance of one sex. We should notice, however, that in all four cases the daughter is more like the mother than the son is. On the other hand the daughter is more like the father than the son is in horse and dog, the sex similarity being only preserved in the case of eye-colour in man. We may safely say that the inheritance of pigmentation cannot differ widely from ·50 for all our series.

If we turn to parental inheritance in the case of dogs selected for record we see that the correlation has been reduced, a result which is the general rule whenever selection takes place. The reducing factor is ·875. Being completely ignorant of the relative standard deviations of the material under consideration, we can hardly reach a more scientific measure of the selection that takes place in record than this reducing factor. But its value is sufficient to show us that our original hesitation to use the greyhound stud-book was justifiable; the correlation of parent and offspring is sensibly reduced by selection in recording. Mr Howard Collins' data enable us, however, to roughly allow for this selection; the corrected values are indicated in the last column of Table IV, and we shall proceed to use a like correction in the following paragraph.

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* See *R. S. Proc.* Vol. 66, p. 159 ftn. Increased information as to inheritance in dogs confirms the view that the sires given in the Basset Stud-book are unreliable.

(6) *On Direct Inheritance. Grandparental Correlations.* We can here unfortunately only deal with the data from the stud-books. The greyhounds, whose offsprings were recorded for Mr Howard Collins, appear to be in great bulk, if not entirely, well-known hounds whose names are in the stud-books. The selection arises from only one or two individuals in each litter being recorded in the stud-books. This, as we have seen, weakens the correlation; possibly it arises because the offspring of more fashionable colours only are recorded in the case of a litter, the parents of which may be of less fashionable colours. If we consider grandchildren of stud-book parents, then there has clearly been a selection out of the litters of this generation, not only of some members of each litter, but of whole litters, because certain parents have been omitted from record altogether, as the rejected members of the litters of the first generation. Now the problem thus stated becomes undoubtedly a complex one, as the reduction for influence of selection on correlation, if the selection extends over several generations, is by no means easy to determine. But it seems not unreasonable to suppose that the total distribution of colour in the sporting greyhound, although probably subject to secular change, is not changing very rapidly. In other words, the effect of selection for *breeding* is to maintain a nearly constant colour distribution for a few generations. If this be so, the chief effect of selection in record is due to the weakening of the correlation by selection of offspring and not to the selection of the breeding parents or grandparents. Accordingly it seems to us that all we can do is to divide the grandparental correlations we find from stud-book pedigrees by the factor ·875, and treat these as the best approximations available to the grandparental correlations. We have then the following results.

TABLE VI. *Grandparental Correlations.*

Mean Square Contingency 36-fold tables.

Grandparent and Offspring	Number	Raw Value*	Probable Reduced Value
Paternal Grandsire and Dog ...	952	·275	·314
Paternal Grandsire and Bitch ...	893	·229	·261
Maternal Grandsire and Dog ...	939	·264	·301
Maternal Grandsire and Bitch ...	888	·336	·384
Paternal Grandam and Dog ...	947	·322	·368
Paternal Grandam and Bitch ...	900	·272	·311
Maternal Grandam and Dog ...	911	·291	·332
Maternal Grandam and Bitch ...	863	·338	·386
Mean	—	·291	·332

---

* The grandparental tables treated by the fourfold method gave—owing to some extent to paucity of number—rather irregular results. The mean of 16 fourfold tables Red A and Black B was ·213, and of sixteen 16-fold and 25-fold contingency E and F tables ·247, both less than the 36-fold tables.

It would thus appear that the grandparental correlation cannot be very different from the mean value $\frac{1}{3}$.

If we compare the results now obtained with earlier pigmentation series we have the following table:

TABLE VII.

Grandparental Relationship.

Grandparent and Offspring	Man Eye-Colour	Horse Coat-Colour	Greyhound Coat-Colour	Mean
Paternal Grandfather and Son ...	·421	·324	·314	·353
Paternal Grandfather and Daughter...	·380	·361	·261	·334
Maternal Grandfather and Son ...	·372	·359	·301	·344
Maternal Grandfather and Daughter...	·297	·312	·384	·331
Paternal Grandmother and Son ...	·272	·309	·368	·316
Paternal Grandmother and Daughter	·221	·204	·311	·245
Maternal Grandmother and Son ...	·252	·261	·332	·282
Maternal Grandmother and Daughter	·318	·235*	·386	·313
Mean	·317	·296	·332	·315

We conclude from this that as in the case of parents, so in the case of grandparents, there is no substantial difference in pigmentation inheritance between man, horse and greyhound. We may reasonably hold that a geometrical series:

$$\tfrac{1}{2},\ \tfrac{1}{2}\times\tfrac{2}{3},\ \tfrac{1}{2}\times(\tfrac{2}{3})^2,\ \tfrac{1}{2}\times(\tfrac{2}{3})^3,\ \ldots$$

will express the decreasing correlations between offspring and ancestry as closely for the greyhound as it does for man and horse[†].

The evidence in favour of a change of sex weakening the intensity of hereditary influence is of a rather doubtful kind. It has been shown to hold for eye-colour in man by Pearson[‡], both in the case of direct and collateral heredity, and by Lutz[§] for further data in the case of direct inheritance. It does not appear to be markedly true for coat-colour in horses. For greyhounds it is not absolutely true, although the differences are of the probable-error order in the case of the unselected parental relations. Here the sire, as in the case of the horse, has a more marked influence on the coat-colour of the daughter than on that of the son, while the dam for man, for horse and for both cases of dogs is more influential in the case of the daughter than in that of the son. In the grandparental series it does however appear to be true; thus we find:

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[*] Erroneously given as ·2392 instead of ·2351 owing to a slip in the value used for log k in finding the equation for r in *Biometrika*, Vol. II. p. 231. The value for k is correct, the equation for r slightly incorrect.

[†] See "The Law of Ancestral Heredity," *Biometrika*, Vol. II. pp. 211 *et seq.*

[‡] *Phil. Trans.* Vol. 195, A, pp. 114—117.

[§] *Biometrika*, Vol. II. pp. 237—240.

Grandparental correlations with regard to change of sex:

Mean value no change of sex: ·350.
Mean value one change of sex: ·336.
Mean value two changes of sex: ·306.

It is further true for the selection in record values of the parental correlations[*]. Thus we are inclined to think that there really exists a weakening of inheritance with change of sex in the case of the greyhound, but that it is so small that it is liable to be screened by the probable errors of the results.

On the whole, for direct inheritance of pigmentation, the greyhound falls quite well into the system formerly found for man and horse.

(7) *Collateral Resemblance in the First Degree.* From the material available on Mr Howard Collins' schedules we could only obtain the degree of resemblance between siblings of the same litter. There was no possibility of getting siblings from different litters except by appeal to the stud-books with their selection for record. Since selection for record depends on the personal equation of the breeder, and the points he selects may to some extent involve coat-colour, the tendency accordingly ought to be to emphasise rather than reduce the fraternal correlation. We find, however (Table VIII), that when we compare the unselected record of the schedules for the *same* litter with the selected record of the stud-books for *different* litters that the values are much reduced, i.e. from ·676 to ·529 on the average. Our first idea was that this great reduction must be due to the fact that we are in one case considering siblings from the *same* and in the other case from *different* litters, or that there must be a sensible difference in the degree of resemblance in the two cases. This was opposed to our experience in the case of Basset Hounds[†]. To confirm the supposition in the case of the greyhound, we worked out from the stud-books all three sibling relationships for the case of siblings from the *same* litter. To our great surprise the result was only slightly in excess of the result obtained for siblings from different litters. In other words, for the greyhound if the *same* material was used in both cases, the conclusion reached for the Basset Hound seemed to apply, i.e. there was no very marked difference in fraternal resemblance when the siblings were and were not from the same litter. We were thus left in considerable doubt as to what interpretation could be put on the fact that fraternal correlation between members of the same litter when found from the schedules and from the stud-books was so markedly different. It seemed difficult to believe that it could be due to selection for record, because it appeared to us that this ought, as far as it influenced colour, to tend to increase the correlation. On examining our totals for the two cases we noted one point which might conceivably throw light on the matter. In the schedules we had 651 pairs of parents, giving rise to 7484 pairs

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[*] The means for unselected and corrected selected values of parental correlation give ·539 for no change of sex and ·524 for one change of sex, a slight difference.

[†] *Royal Soc. Proc.* Vol. 66, p. 158.

of brothers or about 11·5 pairs to each pair of parents; brothers of the same litter from the stud-book were given by 532 pairs of parents and provided 2144 fraternal pairs, or about four pairs to each pair of parents; lastly, brothers of different litters from the stud-book were provided by 258 pairs of parents, and these gave 1044 pairs of brethren, or again about four to each pair of parents. Could it be that this difference in the number of brethren to each pair of parents was the source of the large drop in correlation as we passed from schedules to stud-book? This point was then taken up and investigated*. The members of a litter were given numbers, 1, 2, 3, ... and these were put on tickets and pairs of these tickets drawn at random. In this way 2086 pairs of brothers were obtained, no brother being used with more than one other brother. The table thus obtained is given as Table MMMM in the Appendix. The correlation obtained by the 36-fold table is ·6697, while for 7484 brothers using *every* brother with every other brother it is ·6607. The difference is in fact insensible, but the larger correlation is in the series of *non-repeated* brothers. We conclude therefore that the difference between the fraternal correlation for brethren from the same litter as taken from the schedules and from the stud-book is not due to any purely arithmetical effect of taking many pairs from large litters. The only other explanation we can give, but we see no means at present of testing its truth, lies in the view that the colours of the litter were taken at a much earlier stage for Mr Howard Collins' schedules, than for the stud-book. In the latter cases dogs are often not entered for a year or two. It is possible therefore that the litter as a whole is more alike

TABLE VIII.

Collateral Heredity. Resemblance of Siblings.

Nature of Sibling Pair	Unselected Record				Selected Record			
	Same Litter, Repeated Brothers		Same Litter, Non-repeated Brothers		Same Litter		Different Litters	
	No.	Correlation	No.	Correlation	No.	Correlation	No.	Correlation
Dog and Dog ...	7484	·661	2086	·670	2144	·524	1044	·521
Bitch and Bitch	6542	·700	—	—	2002	·595	1010	·558
Dog and Bitch	7175	·669	—	—	2864	·558	1031	·509
Mean ...	—	·676	—	·670	—	·559	—	·529

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* The whole problem is a difficult one, there are so many statistical pitfalls surrounding it. Theoretically it would seem that both for fraternal and homotypic correlations the increase in the number of brothers or of homotypes taken from each unit ought to alter the correlation, actually we cannot find much difference when the same material is worked out with many and with few members of each unit. See the "Homotyposis" memoir, *Phil. Trans.* Vol. 197, A, pp. 310—313; the memoir on "Mendel's Principles," *Phil. Trans.* Vol. 203, A, pp. 74—77 and the paper on "Telegony in Man," *R. S. Proc.* Vol. 60, p. 279.

in the puppy-stage than the siblings are at a later age, and accordingly this may account for the lessened resemblance of stud-book pairs of brethren. It may be possible later to test this, but at present we can only throw it out as a suggestion, we see no other way to account for the anomalous results of the Table.

The last column gives a result agreeing remarkably well with that for Basset Hounds from different litters, but the want of agreement between the first and last column is very striking. We can only ask: Is it due to record at too early a stage?

The above results for fraternal correlation were all found by Contingency D method, i.e. that of mean square contingency for a 36-fold table. For comparative purposes three fourfold division tables were worked out by method Red A and another three by method Black B. We obtained the results given below in Table IX.

TABLE IX.

Mean Sibling Resemblance.

Method	Same Litter Schedules	Different Litter Stud-book
36-fold Contingency D	·676	·529
Two fourfold Divisions A and B	·680	·538
16-fold and 25-fold Contingency E and F...	·640	·498

We see from this that a 36-fold contingency table gives results in sensible agreement with those to be found from the old fourfold division method, while in 16-fold and 25-fold tables the result is very slightly less, showing that the grouping is hardly fine enough. We now pass to the comparison with man and horse, the

TABLE X.

Resemblance in Pigment of Siblings.

Nature of Sibling Pair	Man		Horse	Dog, Coat-Colour				
				Greyhound			Basset Hound	
	Eye-Colour	Hair-Colour	Coat-Colour	Same Litter		Different Litters	Same Litter	Different Litters
				Schedules	Stud-book			
Brother and Brother	·517	·620	·623	·661	·524	·521	·508	·526
Sister and Sister ...	·446	·570	·693	·700	·595	·558		
Brother and Sister...	·462	·550	·583	·669	·558	·509		
Mean ...	·475	·580	·633	·676	·559	·529	·508	·526

data for which are given in the memoirs cited below*. The results are given in Table X. We see that we have here a very considerable range of values, that the Basset Hounds and the Stud-book Greyhounds agree well with the mean value for man†, but that the Thoroughbred Horses and Schedule Greyhounds exceed these values. The only common factor that we see to explain this difference lies possibly in the earlier age of record in the last two cases. The hair-colour changes with growth in the case of children‡, but there is probably greater uniformity in the hair-colour of siblings in the first year of life than at any later age—our records are for children in the bulk between 10 and 14 years old—and this is a stage hardly comparable with that of yearlings and puppies, as far as definiteness of hair-colour is concerned§.

It will be seen from these results that the suggestion made in *Biometrika*, Vol. II. p. 391, that the high value of the greyhound fraternal correlation is due to the action of individual prepotency on members of the same litter, is not confirmed. We consider that in the case of the dog we may safely say that there is no marked difference between the degree of resemblance of siblings of the same and of different litters. After considerable labour we found it impossible to collect enough data from the stud-books for horses to test the same point on twin and non-twin foals of the same parents. Both twins rarely survive to be recorded, and twin foals themselves are infrequent. The point can and will be dealt with on the basis of Darbishire's material for mice. So far, however, even if a co-uterine environment does increase the resemblance of brethren from the same litter in some species, it certainly does not appear to do so for all, and at any rate the high value of fraternal correlation in the case of the greyhound is not due to this source. It is peculiar to the nature of the record. We believe as in the case of the horse it may possibly be due to a mere temporary influence on the somatic characters of the embryonic co-environment. This disappears when the record of the colour is taken at a later stage. Should this view be the correct one the stud-book records would after all turn out to be of more value than the schedule records. We should then conclude that judged from pigmentation the inheritance in greyhounds is given by:

·466 for parental correlation, and ·529 for fraternal correlation (different litters).

These numbers would be in excellent agreement with the corresponding mean values ·460 and ·519 found for physical measurements in man||.

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* *Phil. Trans.* Vol. 195, A, pp. 93 and 106. *Biometrika*, Vol. III. pp. 154 *et seq.* The hair-colour returns have been taken from school children; these children give ·53 for eye-colour—a result close to Greyhound and Basset Hound values for *different* litters.

† The mean value in the case of man for 9 series of physical measurements in the adult is ·519 (*Biometrika*, Vol. II. p. 519) and for 12 series of head-measurements in children is ·513 (*Biometrika*, Vol. III. p. 140).

‡ The correlation is not nearly so great as some have supposed, but of this more on another occasion.

§ In cattle the like difficulty arises. Some are recorded as mere calves and the colour changes a good deal after losing the first coat. Thus a bull calf recorded as a 'fawn' may be ultimately a 'dark fawn' or 'red' bull.

|| *Biometrika*, Vol. II. pp. 378 and 390.

It is possible that the difficulty here suggested, a temporary influence of embryonic co-environment, ought to be more fully regarded when records are taken of breeding experiments, especially in all cases of hair-colour where the 'adult' colour may not be sufficiently closely approximated to until after the loss of the first coat*.

Still we are not prepared to attribute all high fraternal correlations to such a source as too early record. We consider that there is really greater variation in fraternal than in parental resemblances. Some of it may be due to a permanent effect of co-environment, embryonic or not. The problem is one of considerable interest and yet of great difficulty, and we only hope that more light may yet be thrown on it from further reduction of records or direct breeding experiments.

(8) *General Conclusions.* Our reductions of the greyhound data indicate:

(i) That whether there be one or more pigments, no class of greyhound can be looked upon as purely dominant or purely recessive. The colours of the earlier ancestry crop up in the offspring of parents of definite colours. We do not see how Mendelian principles can be in any way applied to the greyhound. We publish, however, the whole of our tabulated data, and are quite ready to receive and work out reasonable suggestions for its statistical reduction on Mendelian lines.

(ii) That as far as ancestry is concerned the biometrical statistical method leads to parental and grandparental correlations sensibly identical with those which have already been found for pigmentation inheritance in man and horse. There can be no question therefore whether the knowledge of the ancestry is or is not important. It is equally important in all three cases, and no good prediction can neglect the high correlations of the ancestry beyond the parents.

(iii) That if we deal only with the stud-book records there is no difference of a marked character between siblings from the same and different litters, and the values of the fraternal correlation reached are in excellent agreement with those found for Basset Hounds and for pigmentation and physical measurements in the case of man. But if we deal with a colour-record made with the litters in a very early stage, we find the highest fraternal correlations yet reached. The nearest approach to them are the coat-colour correlations in the case of the horse, followed at some distance by Dr Warren's values for *Aphis* and *Daphnia*. It is probable that these high fraternal values with fairly uniform parental correlations are due to different sources, possibly to too early recording in the horse and dog, almost certainly to differentiated environment in the case of the insects. We submit, however, that while fraternal correlation 'clusters' between ·5 and ·6, the nature of its variation and its relation to parental correlation are still very obscure.

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* The percentage returns given by Virchow, Pfitzner and others for darkening of the hair with age are fallacious because they are not dealing with the *same* material at different ages. They have neglected (i) the selection of the fitter—health we find to be correlated with hair colour—and (ii) the children in the primary schools (Virchow) are compared with a totally different group and *class* in the high schools. We are returning to this matter in another paper.

(iv) That so far as work on the inheritance of pigmentation in the Biometric Laboratory at University College has yet gone, we find that for man, horse and dog in long series the results are in good agreement, and can be described by the statement that ancestral correlations diminish in a geometrical series and sensibly the same series. We hope shortly to publish two further long series of pigmentation inheritance statistics; should they give results in accordance with those already reached, no further reductions of this kind will be made by us, for we think the generality of the law will have been sufficiently demonstrated. In saying this we do not overlook the vast amount of material now being collected by Darbishire and others on inheritance of pigmentation in mice, but it is unfortunately not in a form to which it is easy to apply the mathematical processes required. The selection is so stringent, when two true breeding strains are crossed, that it is difficult to apply the complex equations for the influence of selection on correlation. What we should especially like to know would be: (*a*) after hybridisation, do or do not the offspring of the hybrids, if mated at random *inter se*, give a stable population? (*b*) If they do give a stable population, do the ancestral correlations diminish or not in a geometrical series? and (*c*) If they do, are their numerical values sensibly or not the same as those we have found for man, horse and dog? If these questions were answered in the affirmative, then it would be more possible to determine the relationship between so-called Mendelian Principles and the Ancestral Law. The latter seems to apply closely to any fairly stable population with random or nearly random mating, even in the matter of pigmentation. According to the Mendelian hypothesis developed by one of us, the offspring of the hybrids should, if mated at random, give a stable population, and this is likely to be true on many other hypotheses. What happens in such a population? According to the view of some Mendelians both factors of the original cross are, as far as some one character at least is concerned, in appearance, elements of such a population; this being so we ought to be able to see, once the stability of such a population of hybrid's offspring is established, much more clearly than at present the relation of the two views to each other. The differences between our man, horse and dog returns and Darbishire's mice returns seem to consist essentially in this: that in the three former or intra-racial results the intra-breeding between differently pigmented members has gone on for generations, while in the latter or inter-racial results there has been separation for generations. But if the offspring of hybrids mated at random give a 'stable' population, then we ought to be able to predict at least certain phenomena with regard to the result of crossing its constituents. What is now quite clear about the mice is that ancestry can be no more neglected in their case than in the cases of man, dog or horse.

APPENDIX I.

36-fold Contingency Tables.

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TABLE α.

Sire.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♂.	P. Bk. ...	204	171	75	35	—	57	542
	M. Bk. ...	103	362	84	89	—	49	687
	Bd. ...	39	64	226	54	3	80	466
	F. ...	51	71	64	129	2	48	365
	W. ...	1	6	2	1	—	3	13
	R. ...	45	38	39	96	—	101	319
	Totals ...	443	712	490	404	5	338	2392

TABLE β.

Sire.

Offspring ♀.	P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
P. Bk. ...	209	147	50	39	—	48	493
M. Bk. ...	94	344	69	78	—	42	627
Bd. ...	41	69	216	41	2	63	432
F. ...	38	53	53	146	5	58	353
W. ...	2	7	3	8	3	3	26
R. ...	32	29	41	83	—	115	300
Totals ...	416	649	432	395	10	329	2231

TABLE χ.

Dam.

Offspring ♂.	P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
P. Bk. ...	259	98	53	59	5	66	540
M. Bk. ...	118	300	66	113	15	69	681
Bd. ...	70	69	207	57	8	58	469
F. ...	34	85	62	117	7	59	364
W. ...	2	14	4	5	3	5	33
R. ...	42	48	46	59	1	136	332
Totals ...	525	614	438	410	39	393	2419

TABLE δ.

Dam.

Offspring ♀.	P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
P. Bk. ...	247	96	49	47	—	62	501
M. Bk. ...	95	280	62	100	14	62	613
Bd. ...	56	82	175	48	5	67	433
F. ...	51	82	50	96	10	62	351
W. ...	1	9	8	5	4	4	31
R. ...	39	34	41	44	2	148	308
Totals ...	489	583	385	340	35	405	2237

TABLE *aa*.

Sire.

Offspring ♂.	P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
P. Bk. ...	59	57	42	17	1	36	212
M. Bk. ...	23	64	40	27	2	22	178
Bd. ...	16	25	143	28	—	39	251
F. ...	11	24	24	34	—	44	137
W. ...	—	3	2	2	—	4	11
R. ...	18	10	35	36	—	75	174
Totals ...	127	183	286	144	3	220	963

TABLE $\beta\beta$.

Sire.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♀.	P. Bk. ...	44	54	48	18	—	47	211
	M. Bk. ...	13	41	29	26	1	26	136
	Bd. ...	24	31	127	32	—	34	248
	F. ...	12	14	31	36	—	43	136
	W. ...	1	—	7	3	—	5	16
	R. ...	14	14	35	30	—	73	166
	Totals ...	108	154	277	145	1	228	913

TABLE $\chi\chi$.

Dam.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♂.	P. Bk. ...	68	80	29	14	—	21	212
	M. Bk. ...	44	76	17	20	—	21	178
	Bd. ...	32	53	104	23	—	39	251
	F. ...	10	29	25	45	—	28	137
	W. ...	—	3	4	1	1	2	11
	R. ...	27	24	32	25	1	65	174
	Totals ...	181	265	211	128	2	176	963

TABLE $\delta\delta$.

Dam.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♀.	P. Bk. ...	85	68	23	9	—	26	211
	M. Bk. ...	30	67	10	18	2	9	136
	Bd. ...	29	53	100	25	—	41	248
	F. ...	17	28	27	47	—	17	136
	W. ...	2	4	2	5	1	2	16
	R. ...	22	33	23	28	—	60	166
	Totals ...	185	253	185	132	3	155	913

TABLE ϵ.

Paternal Grandsire.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♂.	P. Bk. ...	76	30	45	1	—	58	210
	M. Bk. ...	71	33	27	8	—	38	177
	Bd. ...	73	45	65	8	—	58	249
	F. ...	31	31	31	8	—	31	132
	W. ...	3	3	—	—	—	5	11
	R. ...	22	36	37	4	—	74	173
	Totals ...	276	178	205	29	—	264	952

TABLE ϕ.

Paternal Grandsire.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♀.	P. Bk. ...	64	49	34	6	—	56	209
	M. Bk. ...	43	22	24	7	—	40	136
	Bd. ...	74	35	65	8	—	60	242
	F. ...	36	26	14	7	—	44	127
	W. ...	4	1	1	1	—	8	15
	R. ...	24	38	36	4	—	62	164
	Totals ...	245	171	174	33	—	270	893

TABLE γ.

Maternal Grandsire.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♂.	P. Bk. ...	56	66	40	14	—	30	206
	M. Bk. ...	35	58	34	14	—	28	169
	Bd. ...	74	33	57	15	3	64	246
	F. ...	33	20	30	20	—	31	134
	W. ...	3	1	2	1	—	3	10
	R. ...	36	29	37	17	—	55	174
	Totals ...	237	207	200	81	3	211	939

TABLE θ.

Maternal Grandsire.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♀.	P. Bk. ...	65	64	29	9	2	36	205
	M. Bk. ...	43	41	29	7	—	12	132
	Bd. ...	61	33	67	23	1	54	239
	F. ...	35	18	32	25	—	24	134
	W. ...	4	3	3	3	—	2	15
	R. ...	25	35	26	16	—	61	163
	Totals ...	233	194	186	83	3	189	888

TABLE ι

Paternal Grandam.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♂.	P. Bk. ...	33	57	60	14	—	44	208
	M. Bk. ...	22	47	54	20	3	27	173
	Bd. ...	34	30	117	19	—	49	249
	F. ...	20	25	24	21	7	39	136
	W. ...	3	3	3	—	—	2	11
	R. ...	25	27	46	11	—	61	170
	Totals ...	137	189	304	85	10	222	947

TABLE *F*.

Paternal Grandam.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♀	P. Bk. ...	33	52	48	20	3	49	205
	M. Bk. ...	18	35	36	13	1	29	132
	Bd. ...	34	32	113	20	—	48	247
	F. ...	23	23	37	18	2	32	135
	W. ...	2	1	6	4	—	3	16
	R. ...	31	26	33	13	2	60	165
	Totals ...	141	169	273	88	8	221	900

TABLE *κ*.

Maternal Grandam.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♂.	P. Bk. ...	58	53	25	21	6	32	195
	M. Bk. ...	34	58	27	18	—	28	165
	Bd. ...	49	46	68	37	2	39	241
	F. ...	16	36	16	21	—	41	130
	W. ...	1	1	4	2	—	2	10
	R. ...	28	48	28	15	1	50	170
	Totals ...	186	242	168	114	9	192	911

TABLE λ.

Maternal Grandam.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Offspring ♀.	P. Bk. ...	57	70	17	17	5	32	198
	M. Bk. ...	35	44	10	13	1	26	129
	Bd. ...	54	47	54	37	1	43	236
	F. ...	19	40	15	20	1	34	129
	W. ...	3	4	4	2	2	1	16
	R. ...	19	45	43	18	—	30	155
	Totals ...	187	250	143	107	10	166	863

TABLE *μ*.

First Brother.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Second Brother.	P. Bk. ...	954	340	187	154	3	136	1774
	M. Bk. ...	340	1276	181	204	29	103	2133
	Bd. ...	187	181	758	150	9	100	1385
	F. ...	154	204	150	486	19	91	1104
	W. ...	3	29	9	19	18	11	89
	R. ...	136	103	100	91	11	558	999
	Totals ...	1774	2133	1385	1104	89	999	7484

TABLE ν.

First Sister.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Second Sister.	P. Bk. ...	854	221	117	111	7	132	1442
	M. Bk. ...	221	1194	185	169	20	82	1871
	Bd. ...	117	185	734	115	22	85	1258
	F. ...	111	169	115	454	9	71	929
	W. ...	7	20	22	9	18	17	93
	R. ...	132	82	85	71	17	562	949
	Totals ...	1442	1871	1258	929	93	949	6542

TABLE ω.

Brother.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Sister.	P. Bk. ...	887	340	127	119	5	131	1609
	M. Bk. ...	276	1288	165	262	21	102	2114
	Bd. ...	170	213	745	133	5	82	1348
	F. ...	148	176	143	469	29	115	1080
	W. ...	15	22	20	10	16	9	92
	R. ...	116	72	100	94	10	540	932
	Totals ...	1612	2111	1300	1087	86	979	7175

TABLE $\mu\mu$.

First Brother.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Second Brother.	P. Bk. ...	98	43	47	12	2	30	232
	M. Bk. ...	43	92	27	18	4	16	200
	Bd. ...	47	27	144	26	2	34	280
	F. ...	12	18	26	52	2	31	141
	W. ...	2	4	2	2	—	1	11
	R. ...	30	16	34	31	1	68	180
	Totals ...	232	200	280	141	11	180	1044

TABLE $\nu\nu$.

First Sister.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Second Sister.	P. Bk. ...	88	48	48	24	2	28	238
	M. Bk. ...	48	50	21	22	2	11	154
	Bd. ...	48	21	142	19	4	23	257
	F. ...	24	22	19	48	9	23	145
	W. ...	2	2	4	9	—	3	20
	R. ...	28	11	23	23	3	108	196
	Totals ...	238	154	257	145	20	196	1010

TABLE *ωω*.

Brother.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Sister.	P. Bk. ...	93	53	41	22	1	15	225
	M. Bk. ...	49	63	31	16	2	17	178
	Bd. ...	38	36	143	21	2	29	269
	F. ...	17	23	29	42	2	33	146
	W. ...	2	3	3	1	1	6	16
	R. ...	36	19	22	31	1	88	197
	Totals ...	235	197	269	133	9	188	1031

TABLE *μμμ*.

First Brother.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Second Brother.	P. Bk. ...	220	119	72	37	1	47	496
	M. Bk. ...	119	122	71	47	16	29	504
	Bd. ...	72	71	298	54	10	55	560
	F. ...	37	47	54	78	2	43	261
	W. ...	1	16	10	2	2	1	32
	R. ...	47	29	55	43	1	116	291
	Totals ...	496	504	560	261	32	291	2144

TABLE *ννν*.

First Sister.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Second Sister.	P. Bk. ...	262	84	76	39	2	37	500
	M Bk. ...	84	168	67	42	5	13	379
	Bd. ...	76	67	330	57	8	44	582
	F. ...	39	42	57	112	4	31	285
	W. ...	2	5	8	4	6	2	27
	R. ...	37	13	44	31	2	102	229
	Totals ...	500	379	582	285	27	229	2002

TABLE *ωωω*.

Brother.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Sister.	P. Bk. ...	319	137	115	65	3	51	690
	M. Bk. ...	118	239	75	56	15	29	532
	Bd. ...	108	89	444	78	16	78	813
	F. ...	49	61	82	157	4	69	422
	W. ...	3	8	14	5	—	6	36
	R. ...	50	36	61	55	1	168	371
	Totals ...	647	570	791	416	39	401	2864

TABLE $\mu\mu\mu\mu$.

First Brother.

		P. Bk.	M. Bk.	Bd.	F.	W.	R.	Totals
Second Brother.	P. Bk. ...	250	83	58	45	—	42	478
	M. Bk. ...	83	350	60	51	8	27	579
	Bd. ...	58	60	222	45	3	20	408
	F. ...	45	51	45	132	6	28	307
	W. ...	—	8	3	6	8	4	29
	R. ...	42	27	20	28	4	164	285
	Totals ...	478	579	408	307	29	285	2086

APPENDIX II.

Classified Colour Inheritance Tables.

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The following is the complete series of colour and colour combinations we have met with. In each case the order of the colour is supposed to indicate their relative predominance. In the tables A—D, M—O, first compiled, particoloured dogs were grouped into single classes and not distinguished by placing the predominant colour first. Some breeders decline to distinguish between red and fawn; hence the category R. or F. Where ↓ occurs between two columns or rows in a table, it means that one or more colours do not occur in that table at the point indicated.

1. R. = Red.
2. R. F. = Red and Fawn.
3. R. or F. = Red or Fawn.
4. F. R. = Fawn and Red.
5. R. W. = Red and White.
6. W. R. = White and Red.
7. R. F. W. = Red, Fawn and White.
8. F. R. W. = Fawn, Red and White.
9. W. R. F. = White, Red and Fawn.
10. W. F. R. = White, Fawn and Red.
11. R. or F. W. = Red or Fawn and White.
12. W. R. or F. = White and Red or Fawn.
13. Bd. = Brindle.
14. Bd. Bk. = Brindle and Black.
15. Bk. Bd. = Black and Brindle.
16. Bd. W. = Brindle and White.
17. W. Bd. = White and Brindle.
18. Bd. F. = Brindle and Fawn.
19. F. Bd. = Fawn and Brindle.
20. R. or Bd. = Red or Brindle.
21. R. Bd. = Red and Brindle.
22. R. Bd. W. = Red, Brindle and White.
23. R. Tk. Bk. = Red, Ticked Black.
24. R. Bk. Pts. = Red, Black Points.
25. R. Bk. = Red and Black.
26. R. Bk. W. = Red, Black and White.
27. F. = Fawn.
28. F. W. = Fawn and White.
29. W. F. = White and Fawn.
30. Bd. F. W. = Brindle, Fawn and White.
31. F. Bd. W. = Fawn, Brindle and White.
32. Bd. or F. W. = Brindle or Fawn and White.
33. W. = White.
34. Be. W. = Blue and White.
35. W. Be. = White and Blue.
36. Be. Bd. = Blue Brindle.
37. Be. Bd. Tk. = Blue, Brindle, Ticked.
38. Be. Bd. W. = Blue, Brindle and White.
39. W. Be. Bd. = White, Blue and Brindle.
40. Be. Tk. = Blue Ticked.
41. Be. F. = Blue and Fawn.
42. Be. = Blue.
43. Be. Bk. = Blue and Black.
44. Bk. Be. W. = Black, Blue and White.
45. Be. Bk. W. = Blue, Black and White.
46. Bk. Bd. W. = Black, Brindle and White.
47. Bk. W. = Black and White.
48. W. Bk. = White and Black.
49. Bk. Tk. = Black Ticked.
50. Bk. W. Tk. = Black and White Ticked.
51. W. Bk. Tk. = White and Black Ticked.
52. W. Tk. = White Ticked.
53. F. Bk. = Fawn and Black.
54. F. Bk. W. = Fawn, Black and White.
55. Bk. = Black.

TABLE A.

Sire and Offspring ♂.

Sire.

Offspring ♂.	R.	R. F.	R. or F.	R. W.	R. or F. W.	Bd.	Bd. W.	F.	F. W.	W.	Be. W.	Be. Bd.	Be. Bd. W.	Be. Tk.	Be.	Be. Bk.	Bk. Bd. W.	Bk. W.	Bk. W. Tk.	W. Bk. Tk.	Bk.	Totals
R. ...	59	1	2	8	—	12	11	19	26	—	1	1	—	—	7	—	—	10	5	—	31	193
R. F. ...	2	—	—	—	—	—	1	5	2	—	1	—	—	—	1	—	—	—	—	—	—	12
R. or F. ...	5	—	6	—	—	—	—	4	4	—	—	—	—	—	—	—	—	1	—	2	—	22
R. W. ...	16	—	—	2	—	6	5	1	33	—	2	—	—	—	—	—	2	8	—	—	14	89
R. F.W. ...	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	2
R. or F.W.	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bd. ...	41	3	7	4	—	113	24	19	10	—	1	3	1	—	7	1	1	24	—	—	27	286
Bd. Bk. ...	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	2
Bd. W. ...	13	—	3	7	—	32	45	2	22	3	2	3	—	—	2	—	1	25	—	—	11	171
F. Bd. ...	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	3
R. Bk. ...	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
F. ...	19	1	4	—	—	24	15	46	18	—	2	3	—	—	13	—	1	16	1	—	31	194
F. W. ...	20	—	3	1	—	11	9	21	44	2	4	1	—	—	3	—	—	32	—	—	20	171
Bd. F. W.	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	3
W. ...	3	—	—	—	—	1	1	1	—	—	—	—	—	—	2	—	—	4	—	—	1	13
Be. W. ...	2	—	—	2	—	2	10	8	—	—	9	—	—	—	3	—	—	13	—	—	3	52
Be. Bd. ...	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
Be. Tk. ...	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Be. F. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1
Be. ...	—	—	—	—	2	6	6	8	1	—	14	—	1	—	28	1	—	13	2	—	24	106
Bk. Bd. W.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Bk. W. ...	17	—	14	6	1	27	32	14	54	—	18	—	—	—	6	1	—	247	4	—	69	510
W. Bk. Tk.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	2
F. Bk. ...	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	6	8
F. Bk. W.	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
Bk. ...	38	—	14	5	—	48	23	22	13	—	24	—	2	2	33	1	2	101	7	3	204	542
Totals	240	5	53	37	3	284	184	172	232	5	78	11	4	2	106	4	7	498	19	5	443	2392

TABLE B.

Sire and Offspring ♀.

Sire.

Offspring ♀.	R.	R. or F.	R. W.	R. or F. W.	Bd.	Bd. W.	F.	F. W.	W.	Be. W.	Be. Bd.	Be. Bd. W.	Be.	Be. Bk.	Bk. W.	Bk.	Totals
R.	79	5	3	—	12	5	13	31	—	—	—	—	5	—	14	23	190
R. F. ...	2	—	—	—	3	2	3	4	—	—	—	—	1	—	1	4	20
R. or F. ...	4	6	1	—	1	—	7	—	—	—	—	—	1	—	2	—	22
R. W. ...	11	—	4	—	8	5	1	23	—	—	—	—	—	—	4	3	59
R. F. W. ...	—	—	—	—	2	2	—	—	—	—	—	—	1	—	—	1	6
R. or F. W.	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	1	3
Bd.	42	2	1	—	113	26	18	6	—	2	—	1	9	1	28	33	282
Bd. W. ...	13	1	2	—	34	43	—	16	2	—	1	—	1	—	25	8	146
F. Bd. ...	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	2
R. or Bd. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
R. Tk. Bk. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
F.	23	10	1	—	24	7	50	25	2	5	—	—	6	—	22	24	199
F. W. ...	19	1	3	—	10	12	20	50	3	2	—	—	2	—	14	14	150
Bd. or F. W.	—	—	1	—	—	—	1	—	—	—	—	—	—	—	2	—	4
W.	1	2	—	—	1	2	1	7	3	1	—	—	2	—	4	2	26
Be. W. ...	1	—	3	—	3	8	1	3	—	5	—	—	6	—	9	10	49
Be. Bd. ...	—	—	—	—	1	2	—	—	—	—	—	—	3	—	—	—	6
Be. F. ...	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Be.	1	—	—	—	10	2	4	—	—	18	—	—	24	1	10	19	89
Be. Bk. W....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
Bk. W. ...	28	5	4	1	15	27	17	51	—	16	—	—	7	—	243	56	470
F. Bk. ...	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	9	11
Bk.	32	9	7	—	40	10	25	14	—	26	—	—	22	—	99	209	493
Totals	256	41	31	1	278	154	163	232	10	75	1	1	91	2	479	416	2231

TABLE C.

Dam and Offspring ♂.

Dam.

	Offspring ♂.				↓	↓	↓		↓		↓			↓		↓		↓	↓	↓	↓	
		R.	R. F.	R. or F.	R. W.	R. F. W.	R. or F. W.	Bd.	Bd. W.	F. Bd.	R. Bk. W.	F.	F. W.	W.	Be. W.	Be. F.	Be.	Bk. W.	Bk. W. Tk.	F. Bk.	Bk.	Totals
	R.	63	2	1	16	2	—	13	7	—	—	19	16	—	2	—	2	21	3	2	38	207
	R F. ...	8	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	1	—	—	3	15
	R. or F. ...	4	—	6	—	—	—	6	—	—	—	—	—	—	—	—	—	6	—	—	—	22
→	R. W. ...	18	—	—	15	1	—	3	12	—	—	4	20	1	1	—	—	8	—	—	1	84
→	R. F. W. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—	—	2
→	R. or F. W.	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	2
	Bd. ...	23	—	3	9	—	1	99	32	1	—	34	3	2	5	—	3	13	4	—	58	290
	Bd. Bk. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
	Bd. W. ...	10	5	—	5	—	—	32	42	—	—	9	11	6	6	—	2	34	—	—	12	174
→	F. Bd. ...	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	3
→	R. Bk. Pts. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
→	F. ...	24	6	1	6	1	2	23	3	1	1	54	16	—	5	1	6	20	—	—	20	190
	F. W. ...	7	2	1	9	—	—	14	20	—	—	19	27	7	4	—	12	37	—	—	14	173
→	Bd. F. W. ...	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
→	W. ...	—	—	—	5	—	—	1	3	—	—	2	3	3	6	—	—	8	—	—	2	33
	Be. W. ...	2	—	—	2	—	—	—	1	—	—	3	6	2	11	—	2	12	1	—	9	51
→	Be. Bd. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
→	Be. Bd. W. ...	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2
→	Be. F. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
	Be. ...	12	—	2	—	—	—	5	—	—	—	18	2	—	3	—	11	15	—	—	37	105
→	Bk. W. ...	21	1	—	16	2	3	26	31	—	—	28	55	13	38	—	13	189	2	—	71	509
→	Bk. W. Tk. ...	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	1	—	—	3
→	W. Bk. Tk. ...	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	2
	F. Bk. ...	6	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	7
→	Bk. ...	58	1	—	7	—	—	41	11	—	1	45	14	5	7	1	13	71	6	—	259	540
	Totals	257	18	16	90	6	6	269	165	2	2	236	174	39	88	2	65	440	17	2	525	2419

TABLE D.

Dam and Offspring ♀.

Dam.

Offspring ♀.	R.	R. F.	R. or F.	R. W.	R. F. W.	R. or F. W.	Bd.	Bd. W.	F. Bd.	R. Bk. W.	F.	F. W.	W.	Be. W.	Be. F.	Be.	Bk. W.	Bk. W. Tk.	F. Bk.	Bk.	Totals
R.	67	3	4	23	—	—	15	11	—	—	17	11	—	3	—	1	16	2	—	24	197
R. F. ...	12	—	—	2	—	—	1	—	—	—	3	—	—	1	—	1	—	—	—	2	22
R. or F. ...	2	—	6	—	—	—	4	1	—	—	—	—	—	1	—	—	1	—	—	6	21
R. W. ...	19	—	—	6	1	—	1	6	—	—	5	7	2	1	—	—	5	—	—	7	60
R. F. W. ...	1	—	—	1	—	—	2	—	—	—	—	1	—	—	—	—	—	—	—	—	5
R. or F. W.	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	3
Bd.	26	1	6	11	—	4	90	23	2	—	30	2	—	6	—	6	27	2	—	44	280
Bd. W. ...	11	2	3	3	—	—	19	40	—	1	4	10	5	6	—	3	32	—	—	11	150
F. Bd. ...	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
R. or Bd. ...	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
R. Tk. Bk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
F.	18	2	—	15	1	2	23	1	—	1	51	11	3	2	3	8	22	—	1	34	198
F. W. ...	10	1	—	13	—	—	8	15	1	1	17	17	7	3	1	14	25	1	1	16	151
Bd. F. W. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Bd. or F. W.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
W.	—	—	—	4	—	—	3	5	—	—	2	3	4	2	—	2	5	—	—	1	31
Be. W. ...	2	—	—	1	—	—	1	1	—	—	—	6	5	8	—	3	13	—	—	6	46
Be. Bd. ...	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	3	—	—	—	1	6
Be. F. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Be.	8	—	4	—	—	—	6	1	—	—	21	3	2	3	1	3	6	1	—	28	87
Be. Bk. W. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bk. W. ...	9	4	—	23	—	1	23	24	—	1	24	46	7	52	—	16	170	1	—	60	461
F. Bk. ...	9	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	11
Bk.	56	2	—	3	1	—	39	9	—	1	30	17	—	9	—	14	63	10	—	247	501
Totals	251	16	23	105	3	7	238	139	3	5	205	135	35	97	5	74	388	17	2	489	2237

TABLE AA.

Sire and Offspring ♂.

Sire.

Offspring ♂.	R.	R. F.	R. W.	W. R.	R. F. W.	Bd.	Bd. W.	W. Bd.	F.	F. W.	W. F.	W.	Be. W.	W. Be.	Be. Bd.	Be.	Bk. W.	W. Bk.	Bk. Tk.	Bk. W. Tk.	W. Tk.	Bk.	Totals
R. ...	42	1	—	7	—	9	3	6	8	1	5	—	—	—	—	—	—	2	1	—	—	11	96
R. F. ...	7	1	—	1	—	2	1	—	5	3	1	—	—	—	—	—	1	—	1	—	—	4	27
F. R. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2
R. W. ...	5	—	—	1	—	3	5	1	3	—	2	—	—	—	—	—	2	—	—	—	—	1	23
W. R. ...	4	—	—	3	—	2	—	2	—	—	7	—	—	2	—	—	—	—	—	—	—	1	21
R. F. W. ...	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	3
F. R. W. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
W. R. F. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bd. ...	19	2	—	3	—	62	15	10	4	4	6	—	1	—	4	3	12	4	—	—	—	10	159
Bd. W. ...	3	—	—	2	—	9	11	6	1	—	4	—	—	—	2	—	—	—	—	—	—	3	41
W. Bd. ...	9	—	—	—	—	5	7	9	—	—	7	—	—	—	1	—	2	1	—	—	—	2	43
F. Bd. ...	—	—	—	—	—	—	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	3
Bd. F. ...	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
R. Bd. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
R. Bd. W.	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
F. ...	21	5	1	—	—	6	5	2	20	3	1	—	3	—	1	7	3	1	1	1	1	8	90
F. W. ...	3	—	1	—	—	7	1	1	4	2	1	—	1	—	—	1	1	1	—	—	—	2	26
W. F. ...	8	—	4	1	—	—	—	—	1	—	2	—	—	—	1	—	2	1	—	—	—	1	21
W. ...	2	—	2	—	—	1	1	—	1	—	1	—	—	—	—	1	2	—	—	—	—	—	11
Be. W. ...	1	—	1	—	1	3	1	—	1	—	—	—	—	—	—	1	—	1	—	—	—	—	10
W. Be. ...	—	—	—	—	—	—	—	1	1	—	1	—	—	—	—	4	1	—	—	—	—	—	8
Be. Bd. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
W. Be. Bd.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
Be. F. ...	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Be. ...	4	—	—	—	—	4	—	1	5	—	1	2	—	—	1	6	5	1	1	—	—	4	35
Bk. W. ...	3	—	4	—	1	4	12	2	4	—	6	—	—	—	1	2	24	5	2	—	—	15	85
W. Bk. ...	5	—	—	2	—	4	4	1	1	—	7	—	1	—	—	—	6	2	—	—	—	4	37
Bk. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1
W. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
Bk. ...	32	—	—	4	—	33	6	1	10	1	6	1	2	1	2	9	20	20	2	2	1	59	212
Totals	170	9	13	25	3	154	75	44	70	15	59	3	8	3	13	35	85	39	8	3	2	127	963

TABLE BB.

Sire and Offspring ♀.

Sire.

Offspring ♀.	R.	R. F.	R. W.	W. R.	R. F. W.	Bd.	Bd. W.	W. Bd.	F.	F. W.	W. F.	W.	Be. W.	W. Be.	Be. Bd.	Be.	Bk. W.	W. Bk.	Bk. Tk.	Bk. W. Tk.	W. Tk.	Bk.	Totals
R. ...	39	1	—	3	—	8	3	2	11	1	3	—	—	1	5	4	1	—	1	1	1	8	93
R. F. ...	13	—	—	1	—	6	1	2	3	—	—	—	—	—	—	2	—	—	—	1	—	4	33
F. R. ...	—	1	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	3
R. W. ...	5	—	1	—	—	3	1	2	2	—	1	—	—	—	—	—	—	2	—	—	—	—	17
W. R. ...	5	—	—	2	—	1	—	1	—	—	7	—	—	—	—	—	—	—	—	—	—	1	17
R. F. W. ...	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
W. F. R. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Bd. ...	23	1	—	3	1	55	19	6	6	4	8	—	1	1	6	5	12	4	—	1	—	17	173
Bd. W. ...	5	—	—	—	—	11	6	2	2	1	4	—	—	—	1	—	4	—	—	—	—	1	37
W. Bd. ...	1	—	—	—	—	3	11	6	1	—	6	—	—	—	1	—	3	—	—	—	—	6	38
F. ...	20	3	—	3	—	11	2	2	16	2	3	—	—	—	—	4	4	—	—	—	—	9	79
F. W. ...	8	1	1	—	—	2	8	1	3	2	1	—	1	—	—	2	1	—	—	—	—	3	34
W. F. ...	5	—	2	—	—	—	2	3	5	1	3	—	—	—	—	—	—	2	—	—	—	—	23
W. ...	5	—	—	—	—	1	2	4	—	1	2	—	—	—	—	—	—	—	—	—	—	1	16
Be. W. ...	2	—	—	—	—	1	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	5
W. Be. ...	—	—	—	1	—	—	1	—	—	—	3	—	—	—	—	2	—	—	—	—	—	—	7
Be. ...	1	1	1	—	—	3	1	3	1	1	—	1	—	—	—	2	5	1	2	—	—	5	28
Bk. W. ...	5	—	3	—	—	7	5	—	3	—	5	—	3	—	—	2	11	3	1	1	—	5	54
W. Bk. ...	8	—	—	1	—	3	4	1	3	—	8	—	2	1	—	—	2	3	—	—	—	2	38
Bk. Tk. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2
W. Bk. Tk.	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
W. Tk. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bk. ...	37	4	—	6	—	38	6	3	8	2	8	—	4	—	1	9	29	6	3	2	1	44	211
Totals	186	12	8	21	1	153	72	38	66	16	63	1	11	3	14	32	72	21	7	6	2	108	913

TABLE CC.

Dam and Offspring ♂.

Dam.

Offspring ♂.	R.	R. F.	R. or F.	F. R.	R. W.	W. R.	Bd.	Bd. W.	W. Bd.	Bd. F.	F. Bd.	F.	F. W.	W. F.	W.	Be. W.	W. Be.	Be.	Bk. W.	W. Bk.	Bk. Tk.	Bk. W. Tk.	Bk.	Totals
R.... ...	23	8	2	—	4	2	14	2	1	—	—	6	5	2	—	—	—	3	7	2	—	1	14	96
R. F. ...	3	2	—	—	3	1	2	—	—	—	—	4	—	1	—	—	—	1	2	—	—	—	8	27
F. R. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2
R. W. ...	6	1	—	—	2	3	2	—	1	—	—	—	1	3	—	—	—	—	2	—	—	—	2	23
W. R. ...	2	1	—	—	—	2	3	—	5	—	—	2	1	—	1	—	—	—	3	—	—	—	1	21
R. F. W....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	3
F. R. W....	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
W. R. F....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Bd. ...	20	7	—	2	—	1	45	8	6	—	2	10	3	4	—	3	—	1	20	2	—	1	24	159
Bd. W. ...	3	1	—	—	—	1	14	1	5	—	—	1	3	1	—	—	—	—	5	2	—	—	4	41
W. Bd. ...	1	1	—	1	—	—	8	1	7	—	2	—	1	—	—	—	—	1	5	9	2	—	4	43
Bd. F. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
F. Bd. ...	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	3
R. Bd. ...	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
R. Bd. W.	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
F. ...	13	1	1	—	3	2	15	3	2	—	—	17	6	4	—	—	—	2	12	1	—	1	7	90
F. W. ...	1	—	—	—	—	3	1	1	1	—	—	4	3	2	—	—	1	1	5	2	—	—	1	26
W. F. ...	1	1	—	—	2	—	1	—	1	—	—	2	1	6	—	—	—	—	3	1	—	—	2	21
W. ...	1	—	—	—	1	—	—	1	3	—	—	—	—	1	1	—	—	—	2	1	—	—	—	11
Be. W. ...	1	—	—	—	—	—	—	—	—	—	—	1	2	—	—	1	1	—	2	2	—	—	—	10
W. Be. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	1	1	3	—	—	—	8
Be. Bd. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
W. Be. Bd.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Be. F. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Be. ...	4	—	—	—	—	—	3	1	—	—	—	—	2	—	—	—	—	4	4	1	—	1	15	35
Bk. W. ...	5	3	—	—	3	—	6	4	1	—	—	4	7	1	—	1	2	2	20	5	1	—	20	85
W. Bk. ...	2	—	—	—	—	1	1	—	—	—	—	1	—	—	—	—	1	1	7	13	1	—	9	37
Bk. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
W. Tk. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bk.	18	1	—	—	1	1	18	7	1	3	—	10	2	2	—	2	3	7	51	11	1	5	68	212
Totals	106	27	3	4	19	17	139	30	35	3	4	62	37	29	2	7	8	24	156	56	5	9	181	963

TABLE DD.

Dam and Offspring ♀.

Dam.

Offspring ♀.	R.	R. F.	R. or F.	F. R.	R. W.	W. R.	Bd.	Bd. W.	W. Bd.	Bd. F.	F. Bd.	F.	F. W.	W. F.	W.	Be. W.	W. Be.	Be.	Bk. W.	W. Bk.	Bk. Tk.	Bk. W. Tk.	Bk.	Totals
R. ...	26	4	1	—	6	1	10	1	—	—	—	6	4	4	—	—	—	3	13	4	—	—	10	93
R. F. ...	6	1	—	—	3	2	3	—	—	—	—	1	3	1	—	—	—	1	3	—	—	—	9	33
F. R. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	3
R. W. ...	5	2	—	—	1	1	2	—	1	—	—	1	1	1	—	—	—	—	2	—	—	—	—	17
W. R. ...	1	—	—	—	—	—	2	1	3	—	—	2	1	—	—	—	—	—	3	1	—	—	3	17
R. F. W. ...	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	2
W. F. R. ...	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
Bd. ...	19	6	—	—	—	2	56	7	9	—	1	15	4	3	—	2	—	3	18	4	1	1	22	173
Bd. W. ...	3	1	—	—	2	1	11	1	4	—	—	1	—	—	—	—	1	—	5	1	—	2	4	37
W. Bd. ...	2	1	—	3	1	—	5	—	5	—	1	1	—	1	—	2	—	1	4	8	—	—	3	38
F. ...	4	—	—	—	—	2	13	1	2	1	—	16	6	5	—	2	—	4	8	2	—	—	13	79
F. W. ...	3	—	—	1	—	—	5	2	1	—	—	5	3	5	—	—	—	—	4	1	—	—	4	34
W. F. ...	1	2	—	—	4	—	1	—	1	—	—	2	2	3	—	1	1	—	2	3	—	—	—	23
W. ...	—	2	—	—	—	—	1	—	1	—	—	2	1	2	1	—	—	—	1	3	—	—	2	16
Be. W. ...	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	2	—	—	—	1	5
W. Be. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	3	—	—	1	7
Be. ...	2	—	—	—	1	—	2	—	—	—	—	1	1	1	—	—	—	3	6	—	—	2	9	28
Bk. W. ...	2	1	—	—	—	—	6	—	—	—	—	2	5	3	—	—	1	1	19	2	—	2	10	54
W. Bk. ...	1	—	—	—	—	1	1	—	1	—	—	—	1	1	2	—	2	1	8	12	—	—	7	38
Bk. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	2
W. Bk. Tk.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
W. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
Bk. ...	20	2	—	—	2	2	18	4	—	1	—	5	2	2	—	4	1	5	41	10	2	5	85	211
Totals	96	22	1	4	20	12	136	17	28	2	2	63	36	33	3	12	6	22	144	54	3	12	185	913

TABLE E.

Paternal Grandsire and Offspring ♂.

Paternal Grandsire.

Offspring ♂.	R.	R. or F.	R. W.	W. R.	Bd.	Bd. W.	W. Bd.	F.	F. W.	W. F.	Be. W.	W. Be.	Be.	Bk. W.	W. Bk.	Bk. Tk.	Bk. W. Tk.	Bk.	Totals
R.... ...	43	—	—	1	9	6	1	—	—	3	1	—	11	5	1	1	—	14	96
R. F. ...	7	—	—	—	8	1	—	1	—	—	—	—	2	3	1	—	—	4	27
F. R. ...	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	2
R. W. ...	8	—	1	—	1	6	—	—	—	—	—	—	2	2	1	—	—	1	22
W. R. ...	13	—	—	—	2	—	2	—	—	—	—	—	—	1	2	—	—	1	21
R. F. W....	—	1	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	3
W. R. F....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
F. R. W....	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Bd. ...	24	—	—	1	18	10	13	—	—	5	—	1	18	12	—	2	2	53	159
Bd. W. ...	12	—	—	—	2	7	3	1	—	1	—	—	6	1	—	—	—	8	41
W. Bd. ...	15	—	2	1	5	1	4	—	—	1	—	—	—	3	—	—	—	11	43
F. Bd. ...	2	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	3
Bd. F. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
R. Bd. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
R. Bd. W.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
F.... ...	19	—	—	—	16	5	1	2	—	3	—	—	5	9	—	3	1	23	87
F. W. ...	7	—	—	—	2	2	1	1	1	—	—	—	6	1	—	—	—	5	26
W. F. ...	5	—	—	—	3	1	—	—	—	1	1	—	3	1	1	—	—	3	19
W. ...	4	—	—	1	—	—	—	—	—	—	—	—	—	2	1	—	—	3	11
Be. W. ...	2	—	—	—	3	—	—	1	—	—	—	—	—	1	—	—	—	3	10
W. Be. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	5	8
Be. Bd. ...	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
W. Be. Bd.	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Be. F. ...	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
Be. ...	8	1	—	—	1	3	—	1	—	—	—	—	6	2	—	—	—	13	35
Bk. W. ...	12	1	—	—	10	2	2	3	—	—	—	—	7	10	—	—	—	35	82
W. Bk. ...	11	—	—	1	4	—	—	—	2	1	2	—	1	1	1	—	—	13	37
Bk. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
W. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Bk. ...	53	1	3	1	37	5	3	1	—	—	—	2	10	12	2	2	2	76	210
Totals	247	5	6	6	123	50	32	11	3	15	4	3	78	69	11	8	5	276	952

TABLE F.

Paternal Grandsire and Offspring ♀.

Paternal Grandsire.

Offspring ♀.	R.	R. or F.	R. W.	W. R.	Bd.	Bd. W.	W. Bd.	F.	F. W.	W. F.	Be. W.	W. Be.	Be.	Bk. W.	W. Bk.	Bk. Tk.	Bk. W. Tk.	Bk.	Totals
R. ...	39	—	—	1	9	13	—	1	—	1	—	—	9	5	—	1	1	12	92
R. F. ...	5	—	—	—	6	2	1	1	—	—	—	—	4	5	2	—	1	6	33
F. R. ...	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	3
R. W. ...	4	—	—	—	—	1	1	—	—	—	—	—	1	2	2	1	—	4	16
W. R. ...	13	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	2	17
R. F. W....	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	2
W. F. R....	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Bd. ...	39	—	1	—	22	12	10	1	—	3	—	1	14	9	1	2	—	55	170
Bd. W. ...	11	—	1	—	1	2	5	1	—	—	—	—	4	—	—	—	—	9	34
W. Bd. ...	8	—	—	—	6	2	5	—	—	3	—	—	—	4	—	—	—	10	38
F. ...	17	—	1	1	7	1	1	2	—	2	1	—	10	4	3	1	—	27	78
F. W. ...	14	—	—	1	—	—	1	—	—	1	—	—	4	—	1	—	—	7	29
W. F. ...	7	—	—	3	3	—	1	—	—	2	—	—	2	—	—	—	—	2	20
W. ...	7	—	1	—	—	—	1	—	—	1	—	—	—	1	—	—	—	4	15
Be. W. ...	1	—	—	—	1	—	—	—	—	—	—	—	2	—	—	—	—	1	5
W. Be. ...	1	—	—	1	—	—	—	—	2	—	1	—	—	—	—	—	—	2	7
Be. ...	6	1	—	—	3	2	—	—	—	—	—	—	2	—	2	—	—	12	28
Bk. W. ...	11	1	—	—	8	—	1	1	—	—	—	—	5	5	2	—	—	22	54
W. Bk. ...	16	—	—	—	7	2	—	3	—	1	1	—	1	—	2	—	—	5	38
Bk. Tk. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2
W. Bk. Tk.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
W. Tk. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bk. ...	56	—	—	—	25	8	1	3	1	2	2	2	18	18	3	2	4	64	209
Totals	257	2	4	7	101	45	28	13	4	16	6	3	79	54	16	7	6	245	893

TABLE G.

Maternal Grandsire and Offspring ♂.

Maternal Grandsire.

Offspring ♂.	R.	R. F.	R. or F.	R. W.	W. R.	Bd.	Bd. W.	W. Bd.	F.	F. W.	W. F.	W.	Be. W.	Be. Tk.	Be.	Bk. W.	W. Bk.	Bk. Tk.	Bk. W. Tk.	Bk.	Totals
R. ...	20	2	5	4	—	12	5	2	8	1	1	—	1	—	—	3	3	4	1	24	96
R. F. ...	5	—	4	—	—	1	2	1	3	—	1	—	—	—	—	4	—	—	—	7	28
F. R. ...	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
R. W. ...	9	1	—	1	—	4	—	1	1	—	—	—	—	—	—	4	1	—	—	—	22
W. R. ...	1	—	1	—	1	3	1	2	2	—	—	—	1	—	—	—	4	—	1	4	21
R. F. W.	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	2	—	—	—	—	3
F. R. W....	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
W. R. F....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Bd. ...	39	1	—	1	1	27	6	7	5	2	2	2	3	—	3	13	—	—	—	43	155
Bd. W. ...	13	—	—	—	—	6	—	3	2	—	—	—	1	—	1	3	1	—	—	10	40
W. Bd. ...	8	—	—	—	—	4	—	2	—	3	1	1	—	—	—	2	4	—	—	18	43
F. Bd. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	3
Bd. F. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
R. Bd. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
R. Bd. W.	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
F. ...	16	—	—	2	—	16	4	5	10	1	1	—	—	—	3	4	1	—	3	21	87
F. W. ...	4	—	—	2	1	2	1	—	3	2	1	—	—	—	—	4	—	—	—	6	26
W. F. ...	5	—	1	—	—	1	—	1	2	—	—	—	—	—	1	2	2	—	—	6	21
W. ...	3	—	—	—	—	1	—	1	—	—	1	—	—	—	—	1	—	—	—	3	10
Be. W. ...	2	—	—	1	—	—	1	4	—	—	—	—	—	—	—	1	—	—	—	1	10
W. Be. ...	1	—	—	—	—	—	—	—	—	1	—	—	—	2	2	1	—	—	—	1	8
Be. Bd. ...	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
W. Be. Bd.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Be. F. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Be. ...	4	1	1	2	—	1	1	2	2	—	—	—	—	—	2	6	—	—	—	10	32
Bk. W. ...	11	—	—	2	1	11	2	5	2	1	5	—	1	—	1	17	4	—	—	17	80
W. Bk. ...	2	—	—	—	—	4	1	2	2	—	—	—	—	—	8	6	6	—	—	5	36
Bk. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
W. Tk. ...	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
Bk. ...	23	—	—	5	2	28	11	1	7	1	6	—	1	—	15	32	11	3	4	56	206
Totals	167	5	13	20	6	125	36	39	49	12	20	3	8	2	37	107	37	7	9	237	939

TABLE H.

Maternal Grandsire and Offspring ♀.

Maternal Grandsire.

Offspring ♀.

	R.	R. F.	R. or F.	R. W.	W. R.	Bd.	Bd. W.	W. Bd.	F.	F. W.	W. F.	W.	Be. W.	Be. Tk.	Be.	Bk. W.	W. Bk.	Bk. Tk.	Bk. W. Tk.	Bk.	Totals
R. ...	24	2	3	6	—	10	2	3	4	1	1	—	1	1	—	8	6	3	2	13	90
R. F. ...	3	—	6	1	—	1	3	1	1	4	—	—	1	—	—	4	—	—	—	8	33
F. R. ...	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	3
R. W. ...	7	1	—	—	—	1	—	1	—	1	1	—	—	—	—	3	—	—	—	2	17
W. R. ...	4	—	1	1	—	1	—	1	3	—	—	—	—	—	—	1	4	—	—	1	17
R. F. W. ...	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	2
W. F. R. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Bd. ...	30	1	—	—	3	36	11	5	12	2	2	1	1	—	—	10	5	—	—	51	170
Bd. W. ...	8	—	—	—	—	6	3	2	1	—	2	—	—	—	1	4	1	—	—	5	33
W. Bd. ...	12	—	—	—	—	1	—	3	—	1	3	—	1	—	—	6	4	—	—	5	36
F. ...	13	—	—	1	1	10	6	4	11	3	1	—	—	—	3	2	—	2	—	22	79
F. W. ...	2	—	—	2	—	5	1	2	6	1	1	—	—	1	2	3	—	—	—	8	34
W. F. ...	5	—	—	—	—	2	2	—	2	—	—	—	—	—	2	3	—	—	—	5	21
W. ...	2	—	—	—	—	2	—	1	2	—	1	—	—	—	—	2	—	—	1	4	15
Be. W. ...	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	3	—	—	—	1	5
W. Be. ...	—	—	—	—	—	1	—	—	—	—	—	—	—	1	2	2	—	—	—	1	7
Be. ...	3	—	—	—	—	—	—	3	1	1	—	—	—	1	2	2	—	—	1	13	27
Bk. W. ...	7	—	—	—	—	7	4	1	1	—	1	—	—	—	1	13	2	—	—	14	51
W. Bk. ...	2	—	—	—	—	7	3	1	1	—	—	—	2	—	2	2	5	—	—	13	38
Bk. Tk. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	2
W. Bk. Tk.	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
W. Tk. ...	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
Bk. ...	25	—	—	9	2	18	6	5	5	1	3	2	2	—	13	33	8	3	5	65	205
Totals	149	4	10	20	6	109	44	33	52	15	16	3	8	4	28	101	35	8	10	233	888

TABLE I.

Paternal Grandam and Offspring ♂.

Paternal Grandam.

Offspring ♂.	R.	R. F.	R. or F.	F. or R.	R. W.	W. R.	R. or F. W.	W. R. or F.	Bd.	Bd. W.	W. Bd.	Bd. F.	F.	F. W.	W. F.	W.	Be.	Bk. W.	W. Bk.	Bk. W. Tk.	Bk.	Totals
R. ...	26	1	—	—	8	1	1	—	11	4	5	—	2	—	3	—	5	6	6	—	16	95
R. F. ...	9	—	—	—	1	—	—	—	3	—	1	1	—	—	2	—	—	3	1	1	5	27
R. W. ...	4	—	—	1	2	1	—	—	6	1	2	—	1	—	1	—	—	1	—	—	2	22
W. R. ...	3	—	—	—	2	—	—	—	7	1	4	—	—	—	2	—	—	—	1	—	1	21
R. F. W....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	—	—	—	3
F. R. W....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
W. R. F....	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bd. ...	26	2	—	—	3	1	—	—	28	27	16	—	8	—	5	—	2	18	1	—	22	159
Bd. W. ...	7	—	—	—	2	—	—	—	13	5	3	—	—	—	3	—	1	2	1	—	4	41
W. Bd. ...	7	1	—	—	—	—	—	—	10	4	4	3	—	1	1	—	—	3	2	—	7	43
F. Bd. ...	—	—	—	—	—	—	—	—	1	—	1	—	—	—	1	—	—	—	—	—	—	3
Bd. F. ...	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
R. Bd. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
R. Bd. W.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
F. ...	19	—	—	2	5	—	—	—	8	2	2	—	13	—	3	5	4	6	7	1	12	89
F. W. ...	5	—	—	—	2	—	—	—	7	1	1	—	2	2	1	1	—	2	—	—	2	26
W. F. ...	4	—	—	1	1	—	—	—	2	—	1	—	—	—	—	1	1	4	—	—	6	21
W. ...	2	—	—	—	—	—	—	—	2	—	1	—	—	—	—	—	—	3	—	—	3	11
Be. W. ...	—	—	—	—	—	—	—	—	—	—	1	—	2	1	1	—	2	2	—	—	1	10
W. Be. ...	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	4	—	—	1	7
Be. Bd. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
W. Be. Bd.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Be. F. ...	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
Be. ...	4	—	3	—	—	1	—	1	5	3	1	—	—	1	2	—	2	4	—	—	6	33
Bk. W. ...	7	—	—	—	2	1	1	—	13	2	10	—	4	5	1	1	1	8	10	2	10	78
W. Bk. ...	5	—	—	—	1	—	—	—	8	6	2	—	2	1	—	2	—	3	6	—	4	40
Bk. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
W. Tk. ...	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
Bk. ...	29	4	1	—	5	1	3	1	30	18	12	—	8	3	3	—	2	30	23	2	33	208
Totals	158	8	4	4	35	6	5	2	156	75	69	4	42	14	29	10	21	104	58	6	137	947

TABLE J.

Paternal Grandam and Offspring ♀.

Paternal Grandam.

Offspring ♀.

	R.	R. F.	R. or F.	F. or R.	R. W.	W. R.	R. or F. W.	W. R. or F.	Bd.	Bd. W.	W. Bd.	Bd. F.	F.	F. W.	W. F.	W.	Be.	Bk. W. Tk.	W. Bk.	Bk. W.	Bk.	Totals
R. ...	19	—	—	—	9	—	1	2	11	2	5	—	3	—	3	2	5	4	3	1	20	90
R. F. ...	8	—	—	—	5	—	—	—	3	1	1	—	1	—	2	—	—	5	1	—	7	34
F. R. ...	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
R. W. ...	3	—	—	1	2	—	—	—	2	—	—	—	2	—	1	—	—	4	1	—	1	17
W. R. ...	5	1	—	—	—	—	—	—	5	—	3	—	1	—	—	—	—	—	2	—	1	18
R. F. W....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2
W. F. R....	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bd. ...	32	1	—	—	4	—	—	—	27	23	18	—	10	1	3	—	—	15	11	—	27	172
Bd. W. ...	7	—	—	—	1	1	—	—	10	3	7	—	1	—	2	—	—	2	1	—	3	38
W. Bd. ...	—	1	—	—	1	—	—	—	10	7	8	—	1	1	1	—	—	3	—	—	4	37
F. ...	19	—	—	—	2	—	1	—	10	4	3	—	9	—	2	2	5	5	1	—	14	77
F. W. ...	2	—	—	—	3	2	—	—	9	3	1	1	1	1	2	—	1	5	2	—	2	35
W. F. ...	1	—	—	2	—	—	—	—	4	1	1	—	—	1	2	—	2	2	—	—	7	23
W. ...	3	—	—	—	—	—	—	—	4	—	2	—	—	2	2	—	1	—	—	—	2	16
Be. W. ...	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	3	5
W. Be. ...	—	—	—	—	—	—	—	—	2	—	—	—	2	—	—	—	—	2	—	—	1	7
Be. ...	6	—	1	—	—	1	—	—	2	5	—	—	—	1	2	—	2	3	—	—	2	25
Bk. W. ...	6	1	1	—	1	—	2	—	9	3	—	—	1	5	—	1	2	6	8	1	6	53
W. Bk. ...	5	—	—	—	2	—	—	—	12	3	—	—	—	1	—	—	—	6	4	—	5	38
Bk. Tk. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2
W. Bk. Tk.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
W. Tk. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bk. ...	37	—	1	—	7	—	2	2	21	18	9	—	12	2	6	3	—	30	20	2	33	205
Totals	159	4	3	3	37	5	6	4	141	73	58	1	44	15	29	8	18	92	55	4	141	900

TABLE K.

Maternal Grandam and Offspring ♂.

Maternal Grandam.

Offspring ♂.	R.	R. F.	F. R.	R. W.	W. R.	W. R. or F.	Bd.	Bd. W.	W. Bd.	F.	F. W.	W. F.	W.	Be. W.	Be.	Bk. W.	W. Bk.	Bk. Tk.	Bk. W. Tk.	Bk.	Totals
R. ...	12	5	—	4	3	5	11	4	—	3	1	1	—	—	—	18	7	1	3	16	94
R. F. ...	2	1	—	1	1	2	4	1	—	5	—	—	—	1	2	2	—	1	—	4	27
F. R. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2
R. W. ...	1	1	—	—	3	—	—	1	1	2	—	—	1	—	1	5	—	1	—	4	21
W. R. ...	5	—	—	—	1	2	2	1	—	2	1	—	—	—	—	2	2	—	—	3	21
R. F. W....	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	1	—	—	—	—	3
F. R. W....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
W. R. F.	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bd. ...	22	3	1	3	—	1	20	4	5	16	—	6	1	—	5	19	4	1	1	37	149
Bd. W. ...	4	—	1	1	—	—	6	6	1	1	—	1	1	—	—	5	4	—	—	9	40
W. Bd. ...	1	—	—	1	—	—	7	8	8	4	1	6	—	—	—	2	3	—	—	3	44
F. Bd. ...	—	—	—	—	—	—	—	—	—	2	—	—	—	—	1	—	—	—	—	—	3
Bd. F. ...	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
R. Bd. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
R. Bd. W.	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
F. ...	11	10	—	3	—	—	8	2	2	11	—	3	—	1	—	22	3	1	—	8	85
F. W. ...	7	2	—	1	1	—	—	1	1	1	1	1	—	1	—	3	1	—	—	4	25
W. F. ...	1	1	—	3	1	—	2	—	—	2	1	1	—	—	—	3	1	—	—	4	20
W. ...	2	—	—	—	—	—	2	—	2	—	—	2	—	—	—	—	1	—	—	1	10
Be. W. ...	—	—	—	—	1	—	1	—	—	—	1	—	—	—	—	5	1	—	—	1	10
W. Be. ...	1	—	—	—	1	—	—	—	2	—	—	—	—	—	2	—	—	—	—	1	7
Be. Bd. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
W. Be. Bd.	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Be. F. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Be. ...	3	—	—	1	—	—	3	—	1	2	1	—	—	3	4	3	—	1	—	8	30
Bk. W. ...	9	—	—	1	4	—	9	1	3	5	4	1	—	1	2	17	6	2	—	15	80
W. Bk. ...	3	—	—	1	3	—	4	—	1	3	—	1	—	—	—	5	5	1	—	8	35
Bk. Tk. ...	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
W. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Bk. ...	23	2	—	1	6	—	17	6	2	12	3	6	6	1	6	29	13	2	2	58	195
Totals	109	25	2	21	25	10	102	36	30	71	14	29	9	8	23	142	52	11	6	186	911

TABLE L.

Maternal Grandam and Offspring ♀.

Maternal Grandam.

Offspring ♀.	R.	R. F.	F. R.	R. W.	W. R.	W. R. or F.	Bd.	Bd. W.	W. Bd.	F.	F. W.	W. F.	W.	Be. W.	Be.	Bk. W.	W. Bk.	Bk. Tk.	Bk. W. Tk.	Bk.	Totals
R. ...	8	1	—	2	2	2	15	6	1	4	1	—	—	—	2	19	5	—	3	14	85
R. F. ...	3	—	—	—	2	2	7	3	—	7	—	—	—	1	1	3	1	—	—	3	33
F. R. ...	1	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	3
R. W. ...	—	1	—	—	—	—	1	1	—	1	—	2	—	—	—	7	1	—	—	—	14
W. R. ...	3	1	—	—	—	2	2	1	1	3	—	—	—	—	—	2	—	—	—	2	17
R. F. W. ...	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	2
W. R. F. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bd. ...	16	5	2	3	1	2	9	12	6	9	10	7	1	—	1	22	13	2	1	40	162
Bd. W. ...	5	—	1	1	1	—	4	7	1	2	—	1	—	—	—	3	2	1	—	8	37
W. Bd. ...	3	1	—	2	—	—	9	2	4	5	1	2	—	—	—	2	—	—	—	6	37
F. ...	8	5	—	5	—	—	7	1	2	8	1	3	—	—	—	12	6	3	—	14	75
F. W. ...	5	3	—	2	—	—	—	1	—	2	—	1	1	—	1	9	2	2	—	2	31
W. F. ...	2	2	—	1	1	—	1	1	2	2	2	1	—	—	—	4	1	—	—	3	23
W. ...	—	1	—	—	—	—	2	—	2	1	—	1	2	—	—	3	1	—	—	3	16
Be. W. ...	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	2	5
W. Be. ...	2	—	—	—	1	—	—	—	—	2	—	—	—	—	1	—	—	—	—	1	7
Be. ...	2	—	—	1	1	—	1	—	—	—	1	—	—	2	4	5	1	1	—	7	26
Bk. W. ...	8	—	—	3	3	—	3	—	—	4	—	1	1	1	1	8	4	1	1	10	49
W. Bk. ...	2	—	—	—	1	—	2	—	4	1	1	2	—	—	—	5	6	—	—	14	38
Bk. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	2
W. Bk. Tk.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
W. Tk. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bk. ...	27	—	—	3	2	—	13	2	2	9	2	6	5	2	8	40	18	—	2	57	198
Totals	96	20	3	24	15	8	77	41	25	61	19	27	10	6	19	146	62	10	7	187	863

TABLE M.

Brother and Brother.

First Brother.

Second Brother.	R.	R. F.	R. or F.	R. W.	R. F. W.	R. or F. W.	Bd.	Bd. W.	F. Bd.	F.	F. W.	Bd. F. W.	W.	Be. W.	Be. Bd.	Be. Bd. W.	Be. F.	Be.	Bk. W.	Bk. W. Tk.	W. Bk. Tk.	F. Bk.	Bk.	Totals
R. ...	266	4	1	40	1	—	47	16	—	32	30	—	9	2	—	—	—	11	45	—	—	—	114	618
R. F. ...	4	8	6	—	—	—	—	1	—	4	—	—	—	—	—	—	—	2	1	—	—	—	5	31
R. or F. ...	1	6	52	—	—	—	8	—	—	—	—	—	—	—	—	—	—	1	3	—	—	—	1	72
R. W. ...	40	—	—	128	—	—	11	13	—	7	14	—	2	1	—	—	—	—	37	—	—	—	15	268
R. F. W. ...	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	3
R. or F. W.	—	—	—	—	—	—	1	2	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	7
Bd. ...	47	—	8	11	—	1	350	92	2	66	27	—	4	7	3	—	—	20	43	—	2	1	160	844
Bd. W. ...	16	1	—	13	1	2	92	216	2	16	39	2	5	8	—	1	—	2	92	—	2	—	26	536
F. Bd. ...	—	—	—	—	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	5
F. ...	32	4	—	7	—	—	66	16	—	206	48	—	6	4	1	—	—	28	36	—	—	—	108	562
F. W. ...	30	—	—	14	—	4	27	39	—	48	182	—	13	13	—	—	—	5	108	—	—	—	46	529
Bd. F. W.	—	—	—	—	—	—	—	2	—	—	—	2	—	4	—	—	—	—	5	—	—	—	—	13
W. ...	9	—	—	2	—	—	4	5	—	6	13	—	18	2	—	2	—	3	21	—	1	—	3	89
Be. W. ...	2	—	—	1	—	—	7	8	—	4	13	4	2	36	—	—	—	18	47	—	—	—	15	157
Be. Bd. ...	—	—	—	—	—	—	3	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	4
Be. Bd. W.	—	—	—	—	—	—	—	1	—	—	—	—	2	—	—	—	—	—	1	—	—	—	—	4
Be. F. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	2
Be. ...	11	2	1	—	—	—	20	2	—	28	5	—	3	18	—	—	—	92	24	—	—	—	115	321
Bk. W. ...	45	1	3	37	—	—	43	92	—	36	108	5	21	47	—	1	1	24	924	3	3	—	207	1601
Bk. W. Tk.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	3
W. Bk. Tk.	—	—	—	—	—	—	2	2	—	—	—	—	1	—	—	—	—	—	3	—	—	—	2	10
F. Bk. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	30	—	31
Bk. ...	114	5	1	15	1	—	160	26	1	108	46	—	3	15	—	—	1	115	207	—	2	—	954	1774
Totals	618	31	72	268	3	7	844	536	5	562	529	13	89	157	4	4	2	321	1601	3	10	31	1774	7484

TABLE N.

Sister and Sister.

First Sister.

Second Sister.	R.	R. F.	R. or F.	R. W.	R. F. W.	R. or F. W.	Bd.	Bd. W.	F. Bd.	R. or Bd.	R. Tk. Bk.	F.	F. W.	Bd. F. W.	Bd. or F. W.	W.	Be. W.	Be. Bd.	Be. F.	Be.	Be. Bk. W.	Bk. W.	F. Bk.	Bk.	Totals
R. ...	346	5	—	45	—	1	39	3	—	—	—	27	22	—	—	2	3	—	1	3	—	41	—	104	642
R. F. ...	5	14	—	2	1	—	5	3	—	—	—	4	1	—	—	—	1	—	—	—	—	5	—	3	44
R. or F. ...	—	—	40	—	—	—	13	1	—	—	—	4	1	—	—	1	—	—	—	—	—	1	—	13	74
R. W. ...	45	2	—	44	2	1	4	10	—	—	—	6	1	—	—	14	3	—	—	—	—	20	—	11	163
R. F. W. ...	—	1	—	2	4	—	—	6	—	—	—	—	1	—	—	—	—	—	—	—	—	2	—	1	17
R. or F. W.	1	—	—	1	—	—	1	—	—	—	—	1	2	1	—	—	—	—	—	—	—	2	—	—	9
Bd. ...	39	5	13	4	—	1	442	66	2	—	—	58	13	1	—	12	7	3	—	23	—	42	2	91	824
Bd. W. ...	3	3	1	10	6	—	66	154	1	—	—	6	32	1	1	10	11	—	—	2	—	91	2	25	425
F. Bd. ...	—	—	—	—	—	—	2	1	—	—	—	—	—	1	—	—	2	—	—	—	—	—	—	—	6
R. or Bd. ...	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	2
R. Tk. Bk.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
F. ...	27	4	4	6	—	1	58	6	—	2	—	172	67	1	—	6	4	1	—	18	—	39	—	91	507
F. W. ...	22	1	1	1	1	2	13	32	—	—	—	67	146	—	—	3	15	—	1	5	—	83	—	20	413
Bd. F. W.	—	—	—	—	—	1	1	1	1	—	—	1	—	—	—	—	2	—	—	—	—	—	—	—	7
Bd. or F. W.	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2
W. ...	2	—	1	14	—	—	12	10	—	—	—	6	3	—	—	18	2	—	—	5	—	13	—	7	93
Be. W. ...	3	1	—	3	—	—	7	11	2	—	—	4	15	2	—	2	30	—	1	6	—	47	—	14	148
Be. Bd. ...	—	—	—	—	—	—	3	—	—	—	—	1	—	—	—	—	—	6	—	—	—	—	—	3	13
Be. F. ...	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	1	—	—	4
Be. ...	3	—	—	—	—	—	23	2	—	—	—	18	5	—	—	5	6	—	—	104	—	11	—	90	267
Be. Bk. W.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	2
Bk. W. ...	41	5	1	20	2	2	42	91	—	—	—	39	83	—	1	13	47	—	1	11	2	844	—	114	1359
F. Bk. ...	—	—	—	—	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	74	—	78
Bk. ...	104	3	13	11	1	—	91	25	—	—	1	91	20	—	—	7	14	3	—	90	—	114	—	854	1442
Totals	642	44	74	163	17	9	824	425	6	2	1	507	413	7	2	93	148	13	4	267	2	1359	78	1442	6542

TABLE O.

Brother and Sister.

Brother.

Sister.	R.	R. F.	R. or F.	R. W.	R. F. W.	R. or F. W.	Bd.	Bd. Bk.	Bd. W.	F. Bd.	F.	F. W.	Bd. F. W.	W.	Be. W.	Be. Bd. W.	Be. F.	Be.	Bk. W.	Bk. W. Tk.	W. Bk. Tk.	F. Bk.	Bk.	Totals
R. ...	253	5	1	62	—	—	54	2	5	—	30	32	—	9	4	—	1	11	23	—	—	—	96	588
R. F. ...	6	24	8	2	—	—	8	—	3	—	3	—	—	—	—	—	—	2	1	—	—	—	5	62
R. or F. ...	1	—	29	—	—	1	5	—	4	—	10	—	—	—	—	—	—	—	3	—	—	—	1	54
R. W. ...	50	—	1	90	—	—	6	—	11	—	7	6	—	1	—	—	—	2	24	—	—	—	13	211
R. F. W....	—	1	—	2	2	—	—	—	2	—	—	—	—	—	—	—	—	—	1	—	—	—	1	9
R. or F. W.	1	—	—	—	—	1	—	—	—	—	1	5	—	—	—	—	—	—	—	—	—	—	—	8
Bd. ...	27	2	6	7	—	2	394	3	71	3	55	27	—	1	10	1	—	18	70	2	2	1	147	849
Bd. W. ...	18	1	—	16	1	—	61	—	210	2	13	33	2	4	2	2	—	1	96	—	—	1	22	485
F. Bd. ...	—	—	—	—	—	—	—	—	1	—	1	—	2	—	2	—	—	—	2	—	—	—	—	8
R. or Bd....	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	1	4
R. Tk. Bk.	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	2
F.... ...	41	4	9	9	—	1	61	—	10	—	197	52	—	5	3	—	—	22	38	—	—	—	109	561
F. W. ...	31	—	—	18	—	1	17	—	53	—	49	165	—	24	15	—	1	8	82	—	—	—	39	503
Bd. F. W.	—	—	—	—	—	1	—	—	1	—	—	4	2	—	2	—	—	—	2	—	—	—	—	12
Bd. or F. W.	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	3	—	—	—	—	4
W. ...	5	—	—	3	—	1	9	—	11	—	1	9	—	16	5	—	—	2	14	—	1	—	15	92
Be. W. ...	3	1	—	7	—	—	2	—	9	—	6	13	5	5	35	—	1	6	48	—	—	—	15	156
Be. Bd. ...	—	—	—	—	—	—	8	—	—	—	—	—	—	—	—	—	—	8	—	—	—	—	—	16
Be. Bd. Tk.	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	3
Be. F. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	1	3
Be. ...	15	1	—	1	—	—	19	—	7	—	18	8	—	1	14	—	—	100	36	—	—	—	106	326
Be. Bk. W.	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	2
Bk. W. ...	43	—	3	28	1	—	34	—	82	—	32	180	—	15	47	—	1	13	914	3	1	—	153	1550
F. Bk. ...	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	56	—	58
Bk.	111	4	2	13	1	—	105	—	22	—	97	22	—	5	31	—	—	127	181	—	1	—	887	1609
Totals	606	44	59	258	5	8	787	5	503	5	520	556	11	86	170	3	5	321	1543	5	5	58	1612	7175

TABLE MM.

Brother and Brother.

First Brother.

Second Brother.	R.	R. F.	F. R.	R. W.	W. R.	R. F. W.	W. R. F.	F. R. W.	Bd.	Bd. W.	W. Bd.	F. Bd.	Bd. F.	R. Bd.	R. Bd. W.	F.	F. W.	W. F.	W.	Be. W.	W. Be.	W. Be. Bd.	Be. F.	Be.	Bk. W.	W. Bk.	Bk. Tk.	W. Tk.	Bk.	Totals
R. ...	24	4	—	4	9	—	—	—	7	3	2	—	1	—	—	15	4	—	1	2	—	—	—	2	1	—	—	—	22	101
R. F. ...	4	2	—	—	—	—	—	—	7	—	—	1	—	—	—	1	—	4	—	—	—	—	—	—	4	—	—	—	4	27
F. R. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
R. W. ...	4	—	—	4	1	—	—	—	3	2	1	—	—	—	—	3	2	1	—	—	1	—	—	—	—	—	—	—	4	26
W. R. ...	9	—	—	1	2	—	—	—	2	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17
R. F. W. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	1	—	—	2	—	—	—	—	5
W. R. F. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
F. R. W. ...	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Bd. ...	7	7	—	3	2	—	—	1	60	11	9	4	—	1	—	12	4	—	1	—	—	—	2	5	3	2	—	—	37	171
Bd. W. ...	3	—	—	2	2	—	—	1	11	2	7	—	—	—	2	3	2	1	—	—	—	—	—	1	2	1	—	—	5	45
W. Bd. ...	2	—	—	1	—	—	—	—	9	7	14	—	—	—	—	3	1	—	1	—	1	—	—	—	2	8	—	—	4	53
F. Bd. ...	—	1	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
Bd. F. ...	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
R. Bd. ...	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2
R. Bd. W.	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
F. ...	15	1	—	3	—	—	—	—	12	3	3	—	—	—	—	24	5	4	—	2	—	—	—	2	6	2	—	—	8	90
F. W. ...	4	—	—	2	—	—	—	—	4	2	1	—	—	—	—	5	—	1	1	—	—	—	—	1	1	1	—	—	2	25
W. F. ...	—	4	—	1	—	—	1	—	—	1	—	—	—	—	—	4	1	8	1	—	1	—	—	—	1	1	—	—	2	26
W. ...	1	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	1	1	—	—	1	—	—	—	3	—	—	—	2	11
Be. W. ...	2	—	—	—	—	2	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	5	—	—	—	—	11
W. Be. ...	—	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	1	1	—	—	—	—	—	—	1	1	—	—	6
W. Be. Bd.	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Be. F. ...	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Be. ...	2	—	1	—	—	—	—	—	5	1	—	—	—	—	—	2	1	—	—	—	—	—	—	8	2	—	—	—	16	38
Bk. W. ...	1	4	—	—	—	2	—	—	3	2	2	—	—	—	—	6	1	1	3	5	—	—	—	2	32	9	—	2	20	95
W. Bk. ...	—	—	—	—	—	—	—	—	2	1	8	—	—	—	—	2	1	1	—	—	1	—	—	—	9	12	—	—	7	44
Bk. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
W. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	2
Bk. ...	22	4	—	4	—	—	—	—	37	5	4	—	—	1	—	8	2	2	2	—	—	—	—	16	20	7	—	—	98	232
Totals	101	27	1	26	17	5	1	2	171	45	53	5	2	2	2	90	25	26	11	11	6	1	2	38	95	44	1	2	232	1044

TABLE NN.

Sister and Sister.

First Sister.

Second Sister.	R.	R. F.	R. W.	W. R.	R. F. W.	W. F. R.	Bd.	Bd. W.	W. Bd.	F.	F. W.	W. F.	W.	Be. W.	W. Be.	Be.	Bk. W.	W. Bk.	Bk. Tk.	W. Bk. Tk.	Bk.	Totals
R. ...	60	6	4	4	—	—	6	2	—	4	3	3	3	—	1	2	3	2	—	—	19	122
R. F. ...	6	12	2	—	—	—	7	1	—	3	1	—	—	—	—	—	—	—	—	—	8	40
R. W. ...	4	2	—	—	—	—	3	1	—	2	2	2	—	—	—	—	—	—	—	—	—	16
W. R. ...	4	—	—	4	—	—	3	—	—	—	—	—	—	—	2	—	—	1	—	—	1	15
R. F. W....	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	2
W. F. R....	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
Bd. ...	6	7	3	3	—	—	78	14	8	7	—	3	1	—	—	6	8	—	—	—	39	183
Bd. W. ...	2	1	1	—	—	—	14	8	4	3	2	1	—	—	—	—	—	2	—	—	4	42
W. Bd. ...	—	—	—	—	—	—	8	4	4	1	2	—	3	2	—	—	2	1	—	—	5	32
F. ...	4	3	2	—	—	1	7	3	1	18	9	2	2	1	—	4	3	1	—	1	20	82
F. W. ...	3	1	2	—	—	—	—	2	2	9	2	2	3	—	2	3	1	1	—	—	2	35
W. F. ...	3	—	2	—	2	—	3	1	—	2	2	2	4	1	2	—	—	2	—	—	2	28
W. ...	3	—	—	—	—	—	1	—	3	2	3	4	—	1	—	—	—	1	—	—	2	20
Be. W. ...	—	—	—	—	—	—	—	—	2	1	—	1	1	—	—	—	1	—	—	—	2	8
W. Be. ...	1	—	—	2	—	—	—	—	—	—	2	2	—	—	—	—	1	—	—	—	3	11
Be. ...	2	—	—	—	—	—	6	—	—	4	3	—	—	—	—	4	4	—	—	—	8	31
Bk. W. ...	3	—	—	—	—	—	8	—	2	3	1	—	—	1	1	4	12	6	—	—	22	63
W. Bk. ...	2	—	—	1	—	—	—	2	1	1	1	2	1	—	—	—	6	10	—	—	8	35
Bk. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	4
W. Bk. Tk.	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	2
Bk. ...	19	8	—	1	—	—	39	4	5	20	2	2	2	2	3	8	22	8	4	1	88	238
Totals	122	40	16	15	2	1	183	42	32	82	35	28	20	8	11	31	63	35	4	2	238	1010

TABLE OO.

Brother and Sister.

Brother.

Sister.	R.	R. F.	F. R.	R. W.	W. R.	R. F. W.	W. R. F.	Bd.	Bd. W.	W. Bd.	F. Bd.	Bd. F.	F.	F. W.	W. F.	W.	Be. W.	W. Be.	Be.	Bk. W.	W. Bk.	W. Tk.	Bk.	Totals
R. ...	39	1	—	6	6	—	—	5	2	2	1	—	15	2	1	1	1	2	4	5	3	—	22	118
R. F. ...	6	8	1	—	—	—	1	5	—	2	—	—	4	2	2	—	—	—	—	2	—	—	9	42
F. R. ...	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	4
R. W. ...	6	—	—	2	—	—	—	2	2	—	—	—	2	—	2	—	—	—	—	—	—	—	1	17
W. R. ...	5	—	—	2	3	—	—	—	1	—	—	—	—	1	—	—	—	—	—	2	—	—	2	16
Bd. ...	9	5	—	1	5	—	—	77	9	13	1	1	9	4	2	2	1	—	6	7	1	—	29	182
Bd. W. ...	5	—	—	1	1	—	—	8	7	3	—	—	2	1	—	—	1	—	—	8	1	1	5	44
W. Bd. ...	—	—	—	1	1	—	—	10	5	8	1	—	3	—	—	—	—	—	—	5	5	—	4	43
F. ...	11	6	—	1	—	—	—	10	6	1	—	—	16	4	4	—	3	2	1	5	—	—	8	78
F. W. ...	5	3	—	2	—	1	—	2	3	3	1	—	7	2	1	1	2	2	—	1	1	—	6	43
W. F. ...	2	—	—	2	—	—	—	—	2	1	—	—	3	1	4	1	2	—	—	3	1	—	3	25
W. ...	1	—	—	3	2	—	—	—	—	3	—	—	—	—	1	1	—	—	—	3	—	—	2	16
Be. W. ...	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	3	7
W. Be. ...	—	—	—	—	—	—	—	2	—	1	—	—	—	—	1	—	—	—	1	3	1	—	—	9
Be. ...	2	—	—	1	—	—	—	4	2	—	—	—	—	—	—	—	—	1	8	7	—	—	6	31
Bk. W. ...	1	1	—	—	—	2	—	7	3	4	—	—	7	3	1	—	2	—	1	15	5	—	28	80
W. Bk. ...	3	—	—	—	3	—	—	2	1	5	—	—	2	—	1	2	—	—	—	8	8	—	9	44
Bk. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	3	4
W. Bk. Tk.	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	2
W. Tk. ...	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bk. ...	12	2	—	—	1	—	—	31	6	3	1	—	15	5	2	1	1	1	10	28	13	—	93	225
Totals	109	28	3	22	22	3	1	165	49	49	5	1	85	25	23	9	13	8	32	104	39	1	235	1031

TABLE MMM.

Brother and Brother.

First Brother.

Second Brother.	R.	R. F.	F. R.	R. W.	W. R.	R. F. W.	F. R. W.	W. R. F.	Bd.	Bk. Bd.	Bd. W.	W. Bd.	F. Bd.	R. Bd.	R. Bd. W.	F.	F. W.	W. F.	W.	Be. W.	W. Be.	Be. Bd.	Be.	Bk. W.	W. Bk.	Bk. Tk.	W. Tk.	Bk.	Totals
R. ...	36	4	1	12	4	—	—	—	13	—	6	2	—	1	—	16	5	5	—	—	—	—	4	12	—	—	—	37	158
R. F. ...	4	16	1	—	1	—	—	1	13	—	—	2	—	—	—	2	1	2	—	—	—	—	2	3	—	—	—	8	56
F. R. ...	1	1	—	2	—	—	—	—	—	—	—	1	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	7
R. W. ...	12	—	2	2	2	—	—	—	4	1	5	1	—	1	—	3	2	1	—	—	—	—	—	6	—	—	—	1	43
W. R. ...	4	1	—	2	6	—	—	—	1	—	—	1	—	—	—	1	1	—	1	1	—	—	—	—	1	—	—	1	21
R. F. W....	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	4
F. R. W....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
W. R. F....	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bd. ...	13	13	—	4	1	3	—	—	166	—	17	14	1	1	1	16	6	2	3	4	—	—	8	14	7	—	—	55	349
Bk. Bd. ...	—	—	—	1	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Bd. W. ...	6	—	—	5	—	—	—	—	17	1	36	5	—	1	—	6	10	6	4	2	—	—	2	11	3	—	—	9	124
W. Bd. ...	2	2	1	1	1	—	—	—	14	—	5	10	1	—	—	2	—	4	3	1	1	—	3	8	7	—	—	5	71
F. Bd. ...	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	4
R. Bd. ...	1	—	—	1	—	—	—	—	1	1	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	7
R. Bd. W.	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
F. ...	16	2	1	3	1	1	1	—	16	—	6	2	—	1	—	36	5	7	2	4	—	—	4	7	3	—	—	25	143
F. W. ...	5	1	—	2	1	—	—	—	6	—	10	—	1	—	—	5	6	1	—	4	—	—	1	12	3	—	—	9	67
W. F. ...	5	2	1	1	—	—	—	—	2	—	6	4	—	—	—	7	1	10	—	1	1	—	2	2	3	—	—	3	51
W. ...	—	—	—	—	1	—	—	—	3	—	4	3	—	—	—	2	—	—	2	2	—	—	2	7	4	1	—	1	32
Be. W. ...	—	—	—	—	1	—	—	—	4	—	2	1	—	—	—	4	4	1	2	4	1	—	2	9	3	—	—	2	40
W. Be. ...	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	1	2	—	—	—	1	—	—	—	6
Be. Bd. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Be. ...	4	2	—	—	—	—	—	—	8	—	2	3	—	—	—	4	1	2	2	2	—	—	28	7	2	—	—	21	88
Bk. W. ...	12	3	—	6	—	—	—	—	14	—	11	8	—	—	—	7	12	2	7	9	—	—	7	54	17	—	1	59	229
W. Bk. ...	—	—	—	—	1	—	—	—	7	—	3	7	—	—	—	3	3	3	4	3	1	—	2	17	42	—	—	37	133
Bk. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	6	—	—	7
W. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Bk. ...	37	8	—	1	1	—	—	—	55	—	9	5	1	1	—	25	9	3	1	2	—	1	21	59	37	—	—	220	496
Totals	158	56	7	43	21	4	1	1	349	3	124	71	4	7	1	143	67	51	32	40	6	1	88	229	133	7	1	496	2144

TABLE NNN.

Sister and Sister.

First Sister.

Second Sister.

	R.	R. F.	F. R.	R. W.	W. R.	R. F. W.	Bd.	Bk. Bd.	Bd. W.	W. Bd.	F. Bd.	R. Bd.	F.	F. W.	W. F.	W.	Be. W.	W. Be.	Be.	Bk. W.	W. Bk.	Bk. Tk.	W. Bk. Tk.	Bk.	Totals
R. ...	52	5	1	6	3	—	15	—	6	3	—	—	7	4	3	1	—	—	1	2	2	—	—	19	130
R. F. ...	5	8	—	—	—	—	7	—	2	1	—	—	7	—	2	—	—	—	—	2	—	—	—	11	45
F. R. ...	1	—	4	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	1	1	—	—	—	—	9
R. W. ...	6	—	—	2	—	—	2	1	3	—	—	1	6	1	—	1	—	—	—	3	—	—	—	4	30
W. R. ...	3	—	—	—	4	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	3	13
R. F. W. ...	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Bd. ...	15	7	1	2	1	—	184	—	14	10	2	—	22	8	6	4	1	1	11	12	13	1	—	62	377
Bk. Bd. ...	—	—	—	1	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	3
Bd. W. ...	6	2	—	3	—	—	14	1	38	13	—	1	6	3	3	1	1	1	2	7	3	—	—	10	115
W. Bd. ...	3	1	—	—	1	—	10	—	13	22	—	1	4	1	4	2	—	2	—	4	8	—	—	4	80
F. Bd. ...	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	3
R. Bd. ...	—	—	—	1	—	—	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4
F. ...	7	7	1	6	—	—	22	—	6	4	—	—	34	11	1	2	1	1	6	9	2	—	—	22	142
F. W. ...	4	—	—	1	—	—	8	—	3	1	—	—	11	24	9	—	2	—	1	11	—	—	—	13	88
W. F. ...	3	2	—	—	—	—	6	—	3	4	—	—	1	9	12	2	—	2	2	—	5	—	—	4	55
W. ...	1	—	—	1	—	—	4	—	1	2	1	—	2	—	2	6	—	—	—	—	5	—	—	2	27
Be. W. ...	—	—	—	—	—	—	1	—	1	—	—	—	1	2	—	—	2	—	1	5	1	—	—	2	16
W. Be. ...	—	—	—	—	—	—	1	—	1	2	—	—	1	—	2	—	—	2	4	—	1	—	—	4	18
Be. ...	1	—	1	—	—	—	11	—	2	—	—	—	6	1	2	—	1	4	16	5	1	—	—	24	75
Bk. W. ...	2	2	1	3	—	—	12	—	7	4	—	—	9	11	—	—	5	—	5	54	8	1	—	31	155
W. Bk. ...	2	—	—	—	1	—	13	—	3	8	—	—	2	—	5	5	1	1	1	8	38	—	1	22	111
Bk. Tk. ...	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	3
W. Bk. Tk.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Bk. ...	19	11	—	4	3	—	62	—	10	4	—	—	22	13	4	2	2	4	24	31	22	1	—	262	500
Totals	130	45	9	30	13	2	377	3	115	80	3	4	142	88	55	27	16	18	75	155	111	3	1	500	2002

TABLE OOO.

Brothers and Sisters.

Brothers.

Sisters.	R.	R. F.	F. R.	R. W.	W. R.	R. F. W.	F. R. W.	W. R. F.	Bd.	Bk. Bd.	Bd. W.	W. Bd.	Bd. F.	F. Bd.	R. Bd.	F.	F. W.	W. F.	Bd. F. W.	W.	Be. W.	W. Be.	Be. Bd.	W. Be. Bd.	Be. F.	Be.	Bk. W.	W. Bk.	Bk. Tk.	W. Tk.	Bk.	Totals
R. ...	69	5	3	14	3	1	—	—	19	—	5	2	—	—	—	24	2	5	—	—	—	—	—	—	—	2	9	5	—	—	28	196
R. F. ...	8	20	—	3	—	1	—	1	13	—	2	1	—	—	—	4	—	1	—	—	3	—	—	—	1	5	4	—	—	—	10	77
F. R. ...	—	1	—	—	1	—	—	—	2	—	—	—	—	—	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	15
R. W. ...	8	—	—	8	1	—	—	—	5	1	3	2	—	—	1	7	2	1	—	1	—	—	—	—	—	—	3	—	—	—	4	47
W. R. ...	7	1	—	2	11	—	—	—	2	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	2	30
R. F. W. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
F. R. W. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	1	—	—	—	1	4
Bd. ...	27	13	3	4	5	—	2	—	233	—	31	26	2	—	—	35	6	14	2	3	1	—	—	—	—	8	20	16	—	—	96	547
Bk. Bd. ...	—	—	—	1	—	—	—	—	—	1	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4
Bd. W. ...	6	—	—	5	1	—	—	—	21	1	43	8	—	1	1	2	6	2	1	3	3	—	—	—	—	1	17	5	—	1	6	134
W. Bd. ...	3	—	1	2	4	—	—	—	24	—	14	24	—	2	—	3	1	7	—	10	1	—	2	—	—	1	8	6	—	1	6	120
F. Bd. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	2
R. Bd. ...	—	—	—	1	—	—	—	—	—	1	1	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6
F. ...	24	5	—	5	2	1	—	—	31	—	7	1	—	1	—	59	7	6	—	3	3	1	—	—	—	5	8	1	—	—	36	206
F. W. ...	5	2	—	3	5	—	—	—	10	—	8	4	—	—	—	16	28	5	—	—	8	—	—	—	—	3	20	4	—	—	11	132
W. F. ...	11	3	—	1	2	—	—	—	5	—	8	7	—	—	—	8	7	21	—	1	—	1	—	—	—	1	4	2	—	—	2	84
W. ...	3	2	—	—	1	—	—	—	8	—	6	—	—	—	—	—	—	5	—	—	—	—	—	—	—	2	1	5	—	—	3	36
Be. W. ...	—	—	1	—	—	—	—	—	1	—	1	—	—	—	—	3	1	—	—	1	6	—	—	—	—	—	9	—	—	—	1	24
W. Be. ...	—	—	—	—	1	—	—	—	3	—	—	2	—	—	—	1	2	—	—	1	—	3	1	—	—	1	—	8	—	—	4	27
Be. ...	5	1	—	1	—	—	—	—	7	—	1	—	—	1	—	12	—	—	—	1	3	2	—	—	—	16	5	3	—	—	24	82
Bk. W. ...	10	1	—	5	1	—	—	—	17	—	11	5	—	—	1	9	6	5	—	5	19	2	—	1	—	4	74	16	—	—	61	253
W. Bk. ...	1	2	—	—	—	—	—	—	10	—	4	8	—	—	—	2	4	9	—	7	3	1	—	—	—	5	19	37	—	—	26	138
Bk. Tk. ...	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	3	—	2	7
W. Tk. ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Bk. ...	30	14	—	4	2	—	—	1	93	—	11	5	—	2	1	48	12	5	2	3	4	—	1	—	—	27	64	39	3	—	319	690
Totals	217	70	8	59	40	3	2	2	505	4	158	99	2	7	6	241	87	88	5	39	55	10	4	1	1	81	266	149	6	2	647	2864

TABLE MMMM.

Brother and Brother.

First Brother.

Second Brother.	R.	R. F.	R. or F.	F. R.	R. W.	W. R.	↓ F. R. W.	W. R. or F.	Bd.	↓ Bd. W.	W. Bd.	↓ F. Bd.	↓ F.	F. W.	W. F.	↓ F. Bd. W.	↓ W.	Be. W.	W. Be.	↓ Be. Bd. W.	↓ Be.	↓ Bk. W.	W. Bk.	↓ Bk. W. Tk.	W. Bk. Tk.	W. Tk.	F. Bk.	↓ Bk.	Totals
R. ...	72	—	—	1	6	7	—	—	9	4	—	—	6	5	8	—	2	—	—	—	4	10	3	—	—	—	—	34	171
R. F. ...	—	22	—	—	—	—	—	—	—	1	—	—	2	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	27
R. or F. ...	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	4
F. R. ...	1	—	—	2	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
R. W. ...	6	—	—	—	22	5	—	—	—	—	—	—	1	—	1	—	—	1	—	—	—	6	—	—	—	—	—	5	47
W. R. ...	7	—	—	—	5	8	—	—	1	—	—	—	2	1	—	—	2	—	—	—	—	—	—	—	—	—	—	2	28
→ F. R. W. ...	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
→ W. R. or F.	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Bd. ...	9	—	2	1	—	1	—	—	112	18	6	—	26	2	3	—	—	2	—	—	3	12	5	—	1	1	1	49	254
→ Bd. W. ...	4	1	—	—	—	—	1	—	18	28	5	1	2	4	1	—	1	1	—	—	—	13	7	—	—	—	—	4	91
W. Bd. ...	—	—	—	—	—	—	—	1	6	5	22	—	1	2	4	—	1	—	1	—	1	2	7	—	—	—	—	5	58
→ F. Bd. ...	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
→ F. ...	6	2	—	1	1	2	—	—	26	2	1	—	54	7	5	—	2	2	1	—	7	5	4	—	—	—	—	35	163
F. W. ...	5	—	—	—	—	1	—	1	2	4	2	—	7	28	3	—	1	3	—	—	1	13	4	—	—	—	—	5	80
W. F. ...	8	—	—	—	1	—	—	—	3	1	4	—	5	3	20	—	3	—	1	—	1	2	7	—	—	—	—	5	64
→ F. Bd. W.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	2	—	—	—	—	—	—	3
→ W. ...	2	—	—	—	—	2	—	—	—	1	1	—	2	1	3	—	8	—	—	1	4	4	—	—	—	—	—	—	29
Be. W. ...	—	—	—	—	1	—	—	—	2	1	—	—	2	3	—	1	—	8	1	—	—	6	—	—	—	—	—	3	28
W. Be. ...	—	—	—	—	—	—	—	—	—	—	1	—	1	—	1	—	—	1	2	—	1	2	4	—	—	—	—	3	16
→ Be. Bd. W.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
→ Be. ...	4	—	1	—	—	—	—	—	3	—	1	—	7	1	1	—	4	—	1	—	30	5	3	—	—	—	—	31	92
→ Bk. W. ...	10	1	1	—	6	—	—	—	12	13	2	—	5	13	2	2	4	6	2	—	5	140	30	—	—	—	—	28	282
W. Bk. ...	3	—	—	—	—	—	—	—	5	7	7	—	4	4	7	—	—	—	4	—	3	30	56	1	—	1	—	18	150
→ Bk. W. Tk.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
W. Bk. Tk.	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
W. Tk. ...	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	2
F. Bk. ...	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	—	7
→ Bk. ...	34	1	—	—	5	2	—	—	49	4	5	—	35	5	5	—	—	3	3	—	31	28	18	—	—	—	—	250	478
Totals	171	27	4	5	47	28	1	2	254	91	58	1	163	80	64	3	29	28	16	1	92	282	150	1	1	2	7	478	2086

NOTE ON A RACE OF CLAUSILIA ITALA (VON MARTENS).

BY W. F. R. WELDON.

IN the first number of *Biometrika*, I described the result of measuring one of the elements on which the character of the shell-spiral depends in a race of *Clausilia laminata*. A comparison between the variability of the "peripheral radius" of the shell, in young and in adult individuals, afforded strong evidence that this character was subject to a process of "periodic selection" in the race studied.

In the early spring of 1902, I collected a number of individuals of *C. itala* (v. Martens) on the walls of the Citadel at Brescia, and I made a series of measurements of these, comparing 100 young and 100 adult individuals, as was done for *C. laminata*. The result of this comparison has been entirely negative; there is no evidence of such a difference between young and adults, either in mean character or in variability, as to show that the elimination which occurs during growth is selective with regard to the characters measured. Although it is possible that an explanation of this result, not incompatible with the occurrence of a selective process, may yet be found, I think it right to publish the result at once, because this is, so far as I know, the first case in which young individuals have been shown to resemble the adults of their race, in the degree of development of characters which may perhaps be called specific, so exactly that it is difficult to believe in the occurrence of any selective elimination during growth.

The characters measured will be understood from the diagram, Fig. 1. Each shell was ground on a fine hone, until the columella was approximately cut in half along its whole length, the ground surface having the shape indicated in the diagram. The length of the columella in an adult shell is roughly from 13 to 16 mm., excluding the bent portion connected with the clausilium, while its breadth is never half a millimetre. The plane of a section which passes sensibly through the middle of this long and narrow tube cannot make an important angle with the plane which contains the axis of the shell. In young individuals, where the columella is much shorter, the exactitude attainable by grinding is less; but it is still sufficient for our purposes.

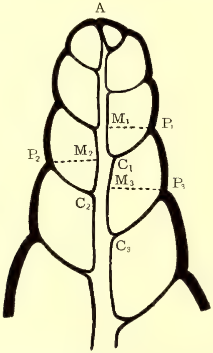

FIG. 1. The upper part of a section through *Clausilia itala*, showing the characters measured.

In any section, points on the peripheral and columellar spirals are exposed, and by passing alternately from one side of the sensibly flat section to the other, we find points on either spiral separated by an angular distance of 180°. It is evident that the relative positions of two points, P_1 and P_2 (Fig. 1) on the peripheral spiral, known to be 180° apart, are determined if we measure in the plane of the section the sides of the triangles AP_1C_1 and AP_2C_2. By proceeding in this way through the whole section, we might determine the law of growth of each side of the fundamental triangle APC, as it revolves round the columella, and so obtain data from which both peripheral and columellar spirals could be reconstructed. An attempt was made to do this; but the columellar end of the septum between two successive whorls, which determines the length of PC, was found to be so indefinite that the measurement of this side of the triangle was abandoned. The "peripheral radius," AP, called P in the tables which follow, and the "columellar radius," AC, called C in the tables, were measured; to obtain a measurement depending on the apical angle PAC, the perpendicular PM, from the peripheral spiral to the columella, was measured; it was found that by means of the perpendicular cross-lines in the eye-piece of a reading microscope it was easy to determine this perpendicular (called in the tables p) with sufficient accuracy.

The measurements were in all cases recorded to 0·01 mm., and care was taken to make them as accurate as possible; for purposes of tabulation, the more variable measures P and C were grouped so that the unit of tabulation was 0·05 mm., the less variable p was tabulated in units each equal to 0·02 mm. The individuals measured were 100 adults and 105 young, the whole number of measures made being well over 9000, though only a part are here discussed.

Having made the measurements of all the sections, it was necessary to find some way of making the results, obtained from one section, comparable with those obtained from another. All that is known about the plane of a given section is, that it is one of the infinite number of planes passing approximately through the axis of the shell. There is no way of determining the angle between the plane of a section and that in which the spiral itself begins.

In comparing sections of *C. laminata*, the measures of the peripheral radius (the only character studied) were tabulated by reference to their angular distance from the plane containing a columellar radius 5 mm. long. Such a method, applied to young and old alike, gives results which are strictly comparable, and it therefore gives a reliable measure of the relative variability in young and in adults; it has however the great disadvantage that the absolute variability is so distorted that the standard deviation of peripheral radii, actually obtained, is nearly worthless as an indication of variability.

For the purposes of the present enquiry, an attempt was made, within the limits of every successive 180°, to determine *first* the mean length and standard deviation of each of the three elements measured, considered by itself, and *secondly* the mean and standard deviation of the array of any one element, associated with a fixed type of one or of both the others. Thus, starting with a columellar radius of 2 mm., in adult shells, and taking every length of this radius which occurred in the following half-revolution, it was found that the range of columellar radii in this particular half-revolution was from 2·00 to 2·49 mm. The mean and standard deviation of this group was determined. Taking the values of P and of p, associated with these values of C, the mean and S.D. of each of these was also determined; then, by making the three correlation-tables between C and P, C and p, P and p, the mean value and the standard deviation of any one of the three sets of measures, associated with fixed type of either or both the others, could also be found.

The mean values of the characters measured, as well as their standard deviations, are given for young and for adults in Table I: it will be seen that they are roughly identical. The degree of identity of mean character in corresponding regions of the young and adult shells cannot, however, be adequately judged from these results. Each entry in Table I, except those in the first column, records the Mean or the Standard Deviation of a character, as determined for a group of cases in which the columellar radius varied in length between the fixed limits given in the first column; but within these limits, the mean value of the columellar radius, and its standard deviation, are largely affected by the mean position and standard deviation of position of the planes in which the sections were cut. These quantities cannot be directly determined, and we have no right to assume without evidence that the mean position of the adult sections, with reference to the origin of the shell-spiral, was exactly the same as that of the sections of young individuals. In order to compare the two sets of results in a more useful way, the regression of peripheral radius-length and that of perpendicular on the length of the columellar radius has been determined from the correlation tables for all the measurements

TABLE I.

Mean Values and Standard Deviations of every Dimension measured for every Half-Revolution of the Shell-Spiral.

(Measurements in millimetres.)

Limits of Columellar Radius	Mean Columellar Radius		S.D. of Columellar Radius		Mean Peripheral Radius		S.D. of Peripheral Radii		Mean Perpendicular		S.D. of Perpendiculars	
	Young	Adult	Young	Adult	Young	Adult	Young	Adult	Young	Adult	Young	Adult
2·00—2·49	2·2012 ±0·0101	2·2201 ±0·0094	0·1503	0·1388	1·9618 ±0·0095	1·9428 ±0·0091	0·1410	0·1348	0·5892 ±0·0028	0·5832 ±0·0031	0·0409	0·0457
2·50—3·09	2·7965 ±0·0106	2·7807 ±0·0118	0·1577	0·1754	2·4518 ±0·0096	2·4470 ±0·0113	0·1429	0·1679	0·6947 ±0·0031	0·6886 ±0·0036	0·0462	0·0537
3·10—3·79	3·4692 ±0·0129	3·4528 ±0·0132	0·1913	0·1954	3·0176 ±0·0132	3·0427 ±0·0125	0·1953	0·1859	0·8165 ±0·0038	0·8191 ±0·0042	0·0563	0·0622
3·80—4·54	4·1498 ±0·0152	4·1334 ±0·0135	0·2258	0·2002	3·6685 ±0·0152	3·6747 ±0·0128	0·2249	0·1896	0·9605 ±0·0051	0·9707 ±0·0046	0·0753	0·0688
4·55—5·49	4·9990 ±0·0181	5·0040 ±0·0194	0·2690	0·2882	4·4666 ±0·0175	4·4703 ±0·0195	0·2592	0·2887	1·1348 ±0·0056	1·1512 ±0·0059	0·0831	0·0871
5·50—6·54	5·9970 ±0·0202	6·0519 ±0·0206	0·2998	0·3050	5·3740 ±0·0206	5·4216 ±0·0200	0·3050	0·2963	1·3447 ±0·0066	1·3272 ±0·0067	0·0982	0·0986
6·55—7·64	6·9687 ±0·0219	7·0755 ±0·0194	0·3245	0·2879	6·3902 ±0·0224	6·4632 ±0·0186	0·3318	0·2758	1·5221 ±0·0075	1·5326 ±0·0060	0·1115	0·0889

of young shells, and the mean value of each of these dimensions, associated with a columellar length identical with the mean found for adults in every half-revolution, has been determined. The two sets of values are given in Table II, from which it will be seen that the values in both series are very close together, and although the differences between the corresponding values of the perpendiculars are considerable in the lower whorls, they are so irregular that it is difficult to regard them as significant. We may therefore say that in young shells, from 7 to 8 mm. in length, the mean length of the peripheral radius, or that of the perpendicular from the peripheral spiral on the columella, corresponding to a given length of columellar radius, is sensibly identical with the mean value of the corresponding character of an adult shell,—or more shortly, the mean spiral is sensibly identical in young and in adults. There is clearly no room here for the suggestion that selection, or any other process, is changing the mean character of the spiral at a rate which produces any sensible effect between one generation and the next. Such an identity between the mean character of young and of adults was demonstrated for the peripheral radii of *C. laminata*, and the speedy establishment of such an identity is to be expected in every local race, if the Law of Ancestral Inheritance be well founded. The only selective process, which remains to be looked for, is what Pearson has called "periodic selection," by which the variability of the race is reduced in every generation during growth, the mean character remaining unchanged in this, though not in all such cases.

TABLE II.

Mean Peripheral Radius and Mean Perpendicular corresponding to identical Values of the Columellar Radius.

Columellar Radius	Mean Peripheral Radius		Mean Perpendicular	
	Adult	Young	Adult	Young
2·2201	1·9428	1·9783	0·5832	0·5919
2·7807	2·4470	2·4383	0·6886	0·6927
3·4528	3·0427	3·0020	0·8191	0·8134
4·1334	3·6747	3·6527	0·9707	0·9569
5·0040	4·4703	4·4711	1·1512	1·1358
6·0519	5·4216	5·4268	1·3272	1·3555
7·0755	6·4632	6·4951	1·5326	1·5432

The standard deviations of the groups of measurements included in every half-revolution studied are given in Table I.; but these are obviously affected by the planes of the sections, and cannot be used in comparing variability. The measure of relative variability, which seems most reliable, is that given by a comparison between the standard deviations of arrays of one dimension in young and adult respectively, corresponding to the same fixed type of either or both of the others.

In order to determine this, the first step was to find the correlations between the dimensions measured, taken in pairs: the correlation coefficients obtained are given in Table III. They were determined for each group corresponding to half a revolution of the shell-spiral, because within these limits the lines of regression were seen to be sensibly straight, and the ordinary measure of the standard deviation of an array could therefore be used with confidence. The high values obtained for correlation between the columellar radius and the peripheral radius seem to show that the measurements were fairly trustworthy, but at the same time the differences between values obtained for corresponding sets of measures in young and in adults are so great and so irregular that it is difficult to see how they can be due to any other cause than error of measurement. In series of only about 100 measures, a single small error of measurement could easily change the second decimal of a correlation coefficient so high as 0·95.

TABLE III.

Correlations between the Dimensions measured for every Half-Revolution of the Shell-Spiral.

Limits of C	r_{CP}		r_{Cp}		r_{pP}	
	Young	Adult	Young	Adult	Young	Adult
2·00—2·49	0·9281 ±0·0094	0·9412 ±0·0077	0·5296 ±0·0485	0·6727 ±0·0369	0·5950 ±0·0436	0·6624 ±0·0379
2·50—3·09	0·9451 ±0·0072	0·9528 ±0·0062	0·5932 ±0·0437	0·7048 ±0·0339	0·6317 ±0·0405	0·7285 ±0·0317
3·10—3·79	0·9351 ±0·0085	0·9439 ±0·0074	0·6340 ±0·0403	0·6589 ±0·0382	0·6552 ±0·0385	0·6090 ±0·0424
3·80—4·54	0·9647 ±0·0047	0·9449 ±0·0072	0·6575 ±0·0383	0·5510 ±0·0470	0·6770 ±0·0365	0·5874 ±0·0442
4·55—5·49	0·9412 ±0·0077	0·9691 ±0·0041	0·6591 ±0·0381	0·6551 ±0·0385	0·6623 ±0·0379	0·6678 ±0·0374
5·50—6·54	0·9450 ±0·0074	0·9491 ±0·0067	0·5980 ±0·0433	0·6205 ±0·0415	0·6448 ±0·0394	0·6412 ±0·0397
6·55—7·64	0·9609 ±0·0052	0·9048 ±0·0122	0·5737 ±0·0452	0·4509 ±0·0537	0·6281 ±0·0408	0·5362 ±0·0481

From the correlation coefficients, and the standard deviations of the various groups, the standard deviations of arrays were calculated in the usual way, the results being given in Table IV. In this table P means peripheral radius, C columellar radius, and p the perpendicular from the peripheral spiral on the columella. The standard deviation of an array of peripheral radii, associated with a fixed length of columellar radius, is given by the value of $\sigma_P \sqrt{1 - r^2_{CP}}$; and similarly in other cases. It will be seen from Table IV. that there is no case in which the standard deviations of the arrays of measures from young shells are consistently greater than those of the corresponding arrays from adult shells. In all cases the values obtained cross and re-cross each other in such a way that we cannot infer greater variability in either series than in the other, and we have therefore no proof that any selective elimination of young occurs.

TABLE IV.

Standard Deviations of Arrays of Peripheral Radii, and of Perpendiculars on the Columella, corresponding to fixed type of one other Dimension. The Determinations made within the limits of Columellar Radius-length indicating half a Revolution of the Shell-spiral.

Limits of Columellar Radius-length	$\sigma_P \sqrt{1 - r^2_{CP}}$		$\sigma_P \sqrt{1 - r^2_{pP}}$		$\sigma_p \sqrt{1 - r^2_{Cp}}$		$\sigma_p \sqrt{1 - r^2_{Pp}}$	
	Young	Adult	Young	Adult	Young	Adult	Young	Adult
2·00—2·49	0·0525	0·0456	0·1125	0·1039	0·0347	0·0338	0·0328	0·0342
2·50—3·09	0·0467	0·0509	0·1110	0·1165	0·0372	0·0381	0·0358	0·0367
3·10—3·79	0·0692	0·0614	0·1453	0·1474	0·0436	0·0468	0·0426	0·0493
3·80—4·54	0·0592	0·0621	0·1675	0·1535	0·0567	0·0574	0·0554	0·0557
4·55—5·49	0·0876	0·0712	0·1953	0·2151	0·0624	0·0658	0·0622	0·0648
5·50—6·54	0·0997	0·0933	0·2312	0·2257	0·0787	0·0773	0·0751	0·0757
6·55—7·64	0·0918	0·1174	0·2589	0·2334	0·0748	0·0916	0·0728	0·0750

To test the possibility of selective elimination still further, the standard deviation of an array was determined in every group of measures, for fixed type of *two* dimensions; the S.D. of peripheral radius-lengths, for fixed type of columellar lengths and perpendiculars, being equal to

$$\sigma_P \sqrt{1 - \frac{r^2_{CP} + r^2_{Pp} - 2r_{CP}r_{Cp}r_{Pp}}{1 - r^2_{Cp}}},$$

a similar expression giving the standard deviation of perpendiculars, for fixed types of columellar and peripheral radii. The results, given in Table V., show no indication that the variability of adult arrays is less than that of the corresponding arrays of young individuals, so that here again the attempt to demonstrate a selective elimination during growth is unsuccessful.

The method employed in determining the variability of the arrays depends of course for its validity on the linear character of the regression in each case. It does not seem worth while to publish the whole series of 21 correlation tables, from which the results were obtained, but the diagram Fig. 2, chosen at random from the series, gives a fair idea of the regression, and in this diagram, at least, there is no doubt of its linear character.

TABLE V.

Standard Deviations of Arrays of P *and* p, *each corresponding to fixed type of both the other Dimensions measured.*

Limits of C	S. D. of P for fixed C and p		S. D. of p for fixed P and C	
	Young	Adult	Young	Adult
2·00—2·49	0·0496	0·0452	0·0327	0·0334
2·50—3·09	0·0449	0·0519	0·0359	0·0367
3·10—3·79	0·0669	0·0611	0·0424	0·0467
3·80—4·54	0·0484	0·0546	0·0550	0·0556
4·55—5·49	0·0863	0·0701	0·0621	0·0647
5·50—6·54	0·0949	0·0912	0·0750	0·0756
6·55—7·64	0·0863	0·1106	0·0858	0·0747

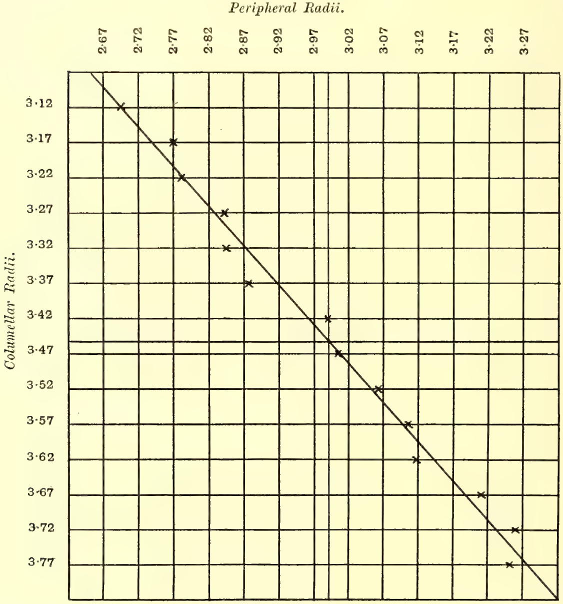

FIG. 2. Regression of Peripheral Radii on Columellar Radii for adult individuals of Columellar radius length from 3·10—3·79 mm.

The negative result so far obtained may conceivably be due to either of three causes:

(1) The characters of the shell-spiral investigated may not be now subject to selective elimination in *C. itala* at all; the correlations already established between the various dimensions measured may result in such mutual adjustment of the parts that within the narrow limits of observed variability any combination of magnitudes of these dimensions, which actually occurs, is sensibly as efficient as any other.

(2) The construction of a garden and of public walks round the Citadel of Brescia is a recent thing, and has possibly led to a recent introduction of *Clausilia*: the condition of the walls of the Citadel is certainly not at present that of an important military fortification; the growth of herbage, the falling out of mortar, and other conditions favourable to the multiplication of *Clausilia*, have certainly been emphasised during the past few years. It is therefore possible that we have here a new colony, multiplying under exceptionally favourable conditions, and so exempt from forms of selection which affect the species in other localities.

(3) The individuals measured, both young and old, were gathered in early spring, after their winter sleep. It is possible that selective elimination of the young takes place largely during the winter, and that individuals of the same length, collected in the autumn, at the close of their period of growth, might be more variable than those which survive the winter.

The data at present available do not permit us to decide which of these suggested possibilities represents the truth. I hope to collect evidence on the point during the autumn of this year; I have ventured to publish this preliminary note because the failure to demonstrate selective elimination in any such case as this appears to me in itself a result of some importance.

MISCELLANEA.

On an Elementary Proof of Sheppard's Formulae for correcting Raw Moments and on other allied Points.

[EDITORIAL.]

Several biometricians having expressed difficulties to the editors concerning the proof and use of Sheppard's corrections in calculating moments, we venture to publish the following elementary consideration of the subject taken from manuscript notes of the past few years. For the complete treatment of the subject the reader must always refer to the original paper*.

Let the equation to the frequency distribution be

$$y=\phi(x),$$

$y\delta x$ being the frequency between x and $x+\delta x$. Let h be the base unit for grouping the raw material. Let N be the total frequency and n_r the frequency on the rth base unit h, between $x_r-\frac{1}{2}h$ and $x_r+\frac{1}{2}h$. Let y_r' be any ordinate corresponding to x_r+x'. Then

$$n_r=\int_{-\frac{1}{2}h}^{+\frac{1}{2}h} y_r' dx' = \int_{-\frac{1}{2}h}^{\frac{1}{2}h} \phi(x_r+x')\,dx'.$$

Now if $\phi(x)$ be a continuous function which can be expanded by Taylor's Theorem, i.e. $\phi^s(x)$ does not become infinite within the range used :

$$n_r=\int_{-\frac{1}{2}h}^{+\frac{1}{2}h}\left\{\phi(x_r)+x'\phi'(x_r)+\frac{x'^2}{1\,.\,2}\phi''(x_r)+\ldots\right\}dx'$$

$$=h\phi(x_r)+\frac{h^3}{24}\phi''(x_r)+\frac{h^5}{1920}\phi^{\text{iv}}(x_r)+\text{etc.}\ \ldots\ldots\ldots\ldots\ldots\ldots\text{(i).}$$

Now x_r is clearly here any abscissa of the frequency curve and this expression gives the frequency on a strip taken anywhere, provided it has a base h and mid-abscissa x_r. It follows that if Σ denote a sum for all values of r,

$$\Sigma\left(n_r(x_r)^s\right)=h\Sigma\left(\phi(x_r)(x_r)^s\right)+\frac{h^3}{24}\Sigma\left(\phi''(x_r)(x_r)^s\right)+\frac{h^5}{1920}\Sigma\left(\phi^{\text{iv}}(x_r)(x_r)^s\right)+\text{etc.}\ \ldots\ldots\text{(ii),}$$

where s is any positive integer.

---

* W. F. Sheppard: "On the Calculation of the most Probable Values of Frequency Constants, for Data arranged according to Equidistant Divisions of a Scale." *Proc. Lond. Math. Soc.* Vol. XXIX, p. 353 et seq.

Now it is a well-known theorem due to Euler and Maclaurin* that if $f(x)$ be any function of x,

$$\int f(x)\,dx = \Sigma h f(x_r) - \left[\frac{h}{2} f(x) + \frac{h^2}{12} f'(x) - \frac{h^3}{720} f'''(x) + \dots\right] \quad \text{.................(iii)},$$

where the term in brackets is to be given its values at the limits of the integration on the left. Hence if $f(x)$, $f'(x)$, $f'''(x)$ etc., all vanish at the ends of the range of values under consideration, we have simply

$$\Sigma h f(x_r) = \int f(x)\,dx \quad \text{.......................................(iv)}.$$

Now suppose $\phi^p(x)\,x^s$ are functions which for different values of p and s are such that they and their differential coefficients vanish at the ends of the range of frequency. Then

$$\Sigma\{n_r(x_r)^s\} = \int \phi(x)\,x^s dx + \frac{h^2}{24}\int \phi''(x)\,x^s dx + \frac{h^4}{1920}\int \phi^{\text{iv}}(x)\,x^s\,dx + \dots \quad \text{............(v)}.$$

But by integrating by parts

$$\int \phi^p(x)\,x^s dx = [\phi^{p-1}(x)\,x^s - s\phi^{p-2}(x)\,x^{s-1} + s(s-1)\,\phi^{p-3}(x)\,x^{s-2} + \dots] \quad \text{.........(vi)}.$$

This clearly vanishes at both limits if p be greater than s. Hence no term of (v) need be retained for which p is greater than s.

Put s successively 0, 1, 2, 3, 4, we find

$$\Sigma(n_r) = \int \phi(x)\,dx = N,$$

$$\Sigma(n_r x_r) = \int \phi(x)\,x dx = N\mu_1',$$

$$\Sigma(n_r x_r^2) = \int \phi(x)\,x^2 dx + 2\,\frac{Nh^2}{24} = N\left(\mu_2' + \frac{1}{12}\,h^2\right),$$

$$\Sigma(n_r x_r^3) = \int \phi(x)\,x^3 dx + 6\,\frac{h^2}{24}\int \phi(x)\,x dx = N\left(\mu_3' + \frac{h^2\mu_1'}{4}\right),$$

$$\Sigma(n_r x_r^4) = \int \phi(x)\,x^4 dx + \frac{h^2}{2}\int \phi(x)\,x^2 dx + \frac{24h^4}{1920}\,N = N\left(\mu_4' + \frac{1}{2}h^2\mu_2' + \frac{1}{80}\,h^4\right) \quad \text{......(vii)}.$$

Here μ_1', μ_2', μ_3', μ_4' multiplied by N are the true first four moments about the axis of y of the frequency curve. If we take the axis of y through the mean, we find $\mu_1' = 0$, and if we write for the moments about the mean $N\mu_2$, $N\mu_3$, $N\mu_4$ and $N\nu_1$, $N\nu_2$, $N\nu_3$, $N\nu_4$ for the moments of the frequencies n_r about the mean, we find, since $\Sigma(n_r x_r^s) = N\nu_s$,

$$\left.\begin{array}{l} \mu_0 = \nu_0 = 1, \quad \mu_1 = \nu_1 = 0 \\ \mu_2 = \nu_2 - \dfrac{h^2}{12}, \quad \mu_3 = \nu_3 \\ \mu_4 = \nu_4 - \dfrac{h^2}{2}\,\nu_2 + \dfrac{7h^4}{240} \end{array}\right\} \quad \text{...................................(viii)}.$$

In other words the area, the centroid and the third moment are not changed by using group frequencies for ordinates, and from the second and fourth moments we have to subtract

$$\frac{1}{12}h^2 \quad \text{and} \quad \frac{1}{2}h^2\nu_2 - \frac{7}{240}h^4$$

respectively, supposing the raw moments already referred to the mean. These are the well-known Sheppard's corrections.

---

* Boole's *Finite Differences*, Chapter V. The expansion of course depends on $f(x)$ satisfying continuity conditions.

It will be noted at once that the assumptions made are (i) that Taylor's Theorem may be applied to the frequency function throughout the range, i.e. $\phi(x)$ and its derivatives must be finite and continuous throughout the range; further (ii) that $x^s\phi^p(x)$, where s and p are any integers, and its derivatives are finite and continuous throughout the range, and (iii) that $\phi(x)$ and its differentials vanish at the limits.

Now (ii) practically flows from (i), but (iii) is a weak spot and must be borne carefully in mind when the corrections are applied. It amounts to saying that the contact is of an indefinitely high order at the ends of the range. This is by no means generally true, the curve frequently meeting the character axis at a finite angle, or even being perpendicular to it. In such cases special processes must be adopted to correct the moments*. The real trouble of the analysis often lies in the fact that until the curve has been fully calculated out, we are not in a position to determine the nature of the contact at the terminals, i.e. we want to know the moments before we can determine whether they ought to be corrected by Sheppard or not. In some cases the graphical representation may suffice to indicate the nature of the contact, but it is by no means conclusive, often indeed misleading.

This arises to some extent from the fact that we usually deal with areas, not ordinates, in plotting such graphical representations. If we accept an expansion up to h^4 as giving approximately enough for practice the value of n_r in terms of y_r, we can deduce a number of quite useful results from equations like (i). For example, let us take the normal curve:

$$y=\frac{N}{\sqrt{2\pi}\,\sigma}e^{-\frac{1}{2}\frac{x^2}{\sigma^2}}.$$

Here
$$\phi''(x)=y\,\frac{x^2-\sigma^2}{\sigma^4},$$

$$\phi^{\text{iv}}(x)=y\,\frac{x^4-6\sigma^2x^2+3\sigma^4}{\sigma^8}.$$

Hence
$$n_r=hy_r\left\{1+\frac{h^2}{24}\frac{x_r^2\sigma^2}{\sigma^4}+\frac{h^4}{1920}\frac{x_r^4-6\sigma^2x_r^2+3\sigma^4}{\sigma^8}\right\}.$$

Now the second and third terms will be largest when x_r is biggest, say $x_r=3\sigma$ in practice. In this case

$$n_r=hy_r\left\{1+\frac{1}{3}\left(\frac{h}{\sigma}\right)^2+\frac{1}{64}\left(\frac{h}{\sigma}\right)^4\right\}.$$

But h will hardly be as large as $\frac{1}{2}\sigma$, or say about 12 groups. Then we have

$$n_r=hy_r\left\{1+\frac{1}{12}+\frac{1}{1024}\right\}.$$

Thus the term in h^4 even at maximum is for practical purposes negligible, but the term in h^2 may amount to as much as 8 per cent. Accordingly we conclude that the frequency may be found from the ordinate in the case of the normal curve by the formula

$$n_r=hy_r\left\{1+\frac{h^2}{24}\frac{x_r^2-\sigma^2}{\sigma^4}\right\}.$$

There is another way of looking at this result. Consider the expression

$$u_r=\frac{N}{\sqrt{2\pi}\,\sigma_0}e^{-\frac{1}{2}\frac{x_r^2}{\sigma_0^2}},$$

and put $\sigma_0^2=\sigma^2+ph^2$, we have on expanding and retaining powers of h up to h^4,

$$u_r=\frac{N}{\sqrt{2\pi}\,\sigma}e^{-\frac{1}{2}\frac{x^2}{\sigma^2}}\left\{1+\frac{ph^2(x_r^2-\sigma^2)}{2\sigma^4}+\frac{p^2h^4}{8}\frac{x_r^4-6\sigma^2x_r^2+3\sigma^4}{\sigma^8}\right\}.$$

---

* See, for example, *Biometrika*, Vol. I. pp. 282—88.

Or, if p be taken $=\frac{1}{12}$

$$u_r=\phi(x_r)+\frac{h^2}{24}\phi''(x_r)+\frac{h^4}{1152}\phi^{\text{iv}}(x_r).$$

Thus $$n_r-hu_r=-\frac{h^4\phi^{\text{iv}}(x_r)}{2880},$$

which is in all practical cases of no importance.

Hence $n_r=h\times u_r$, or the frequencies are given by the ordinates of a normal curve for which the standard deviation is $\sigma^2+\frac{1}{12}h^2$, but if $N\nu_2$ be the 'raw' second moment about the mean we have seen above that $\sigma^2=\nu_2-\frac{1}{12}h^2$. Thus $\sigma_0{}^2=\nu_2$, very closely. Or, we conclude that:

If the ordinates of a normal curve be calculated from the raw second moment value of the standard deviation, these ordinates will more closely represent the actual frequencies than do the ordinates of the true normal curve, which have to be corrected by the factor

$$1+\frac{1}{24}h^2\frac{x_r{}^2-\sigma^2}{\sigma^2}$$

to obtain the actual frequencies.

If therefore our sole object is to compare observed and calculated frequencies for a definite series of groups, there are advantages in using the raw second moment in the equation to the curve. Such a curve has been termed by Sheppard a 'spurious curve of frequency.' Generally if the raw moments be used to calculate such a spurious curve its ordinates will give the frequencies, but the constants of such a curve are not the constants of the true frequency distribution, but functions of h the unit of grouping.

As we want as a rule both the constants of the true frequency distribution (for comparative purposes), and the theoretical frequencies to compare with the observed frequencies, we are in some difficulty in the case of curves, which unlike the normal curve, have not their areas tabled. We have either to calculate the spurious curve as well as the true curve, or devise some process by which the areas of the true curve may be found from its ordinates for small ranges h.

We have used for some time past the following formulae for finding areas in terms of mid-ordinates in the case of skew curves of frequency:

(i) Normal Curve: Origin at mode.

$$y=y_0e^{-\frac{x^2}{2\sigma^2}}.$$

Area of strip on base h

$$=h\times y\left[1+\frac{1}{24}\frac{h^2}{\sigma^2}\frac{x^2-\sigma^2}{\sigma^2}\right].$$

(ii) Curve of type: Origin at mode and $p=a\gamma$.

$$y=y_0\left(1+\frac{x}{a}\right)^p e^{-\gamma x}.$$

Area of strip on base h

$$=h\times y\left[1+\frac{1}{24}\frac{h^2}{\sigma^2}\frac{(\overline{p+1}x^2-p\sigma^2)}{(x+a)^2}\right]$$

(p must be >2, if this is to be of value near the terminal of the curve).

(iii) Curve of type: Origin at mode.

$$y=y_0\left(1+\frac{x}{a_1}\right)^{m_1}\left(1-\frac{x}{a_2}\right)^{m_2}.$$

Area of strip on base h

$$=h\times y\left[1+\frac{h^2}{24}\,\frac{(m_1+m_2)\{x^2(m_1+m_2-1)-\alpha_1\alpha_2\}}{d_1{}^2d_2{}^2}\right],$$

where d_1 and d_2 are the distances of the foot of the ordinate y from the terminals of the range.

(iv) Curve of type: Mode at distance $x_0=-\dfrac{\nu}{2m}$ from origin.

$$y=y_0\frac{1}{\left(1+\dfrac{x^2}{a^2}\right)^m}e^{-\nu\tan^{-1}\frac{x}{a}}.$$

Area of strip on base h

$$=h\times y\left[1+\frac{h^2}{24}\,\frac{2m}{(a^2+x^2)^2}\{\overline{2m+1}\,(x-x_0)^2-(a^2+x_0{}^2)\}\right].$$

Punnett. To face p. 3.3

VOLUME III NOVEMBER, 1904 No. 4

MERISM AND SEX IN "SPINAX NIGER."

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I. INTRODUCTION.

IN spite of the mass of literature steadily accumulating upon the subject, the question of the origin of limbs still remains one of the most vexed problems in vertebrate morphology. The gill-arch theory of Gegenbaur and the side-fold theory with which the name of Balfour is most closely associated each have their supporters. Both theories are so elastic that each without undue stretching may be made to cover all the facts at present known with regard to the comparative anatomy, embryology, and palaeontology of the limbs themselves. There is however one fundamental difference between them. On the gill-arch theory the various positions of the limbs in the meristic series involve the conception of limb-migration or homoeosis. On the side-fold theory these positions may be supposed to be due to processes of excalation or intercalation of segments, though the possibility of homoeosis is not necessarily excluded. Its inclusion however cannot but detract from the simplicity of the theory. Consequently, if on independent grounds the phenomenon of homoeosis is found to be non-existent, the presumption in favour of the side-fold theory is very great. If, on the other hand, this phenomenon can be shown to be a reality, the gill-arch theory must gain considerable support. For with the balance of evidence equally poised, Gegenbaur's theory has the merit of deducing the limbs from a structure already in existence. In the present paper a considerable number of one of the most primitive of living vertebrates has been examined and the meristic variations studied with the aid of biometric methods. The key to the limb question has been sought in the vertebral column, and the evidence there gained in favour of homoeosis lends support to the gill-arch as opposed to the side-fold theory of the origin of the vertebrate limb.

Before passing on to a consideration of the evidence I would here express my sense of obligation to the Government Grant Committee of the Royal Society for opportunities of visiting Norway for material; to Dr Nordgaard, Director of the Marine Biological Station at Bergen, for his most kind assistance in procuring that material; and to Professor Karl Pearson for much generous help in connection with the working out of the statistics.

Material and Methods.

The material brought together consists in all of 567 specimens of *Spinax niger*, of which 263 are adult (100 ♂s and 163 ♀s), whilst the remaining 304 are embryos almost ready to be born (145 ♂s and 159 ♀s). In the adults of both sexes the following points were noted in connection with the vertebrae, spines, and pelvic plexus, though, owing to technical difficulties consequent upon the small size of the embryos, the condition of the pelvic plexus in these was not examined. The raw data are given in the Appendix, Tables 11 to 47.

1. *Whole vertebrae.* As in all Elasmobranchs the vertebral column is composed of whole vertebrae in the trunk region and of half vertebrae in the caudal region. The whole vertebrae are therefore delimited rostrally by the skull and caudally by the half vertebrae. The junction of the whole vertebrae with the skull is rendered fairly simple of determination by the condition of the spino-occipital nerves. When the skull is viewed from the inside a small foramen is seen just below that for the vagus (Plate I, Figs. 4 and 5). This foramen, which is constant in its position, I regard as belonging to the most anterior of the spino-occipital nerves (x). Neither this nerve nor y immediately behind it ever possesses

a dorsal root in the adult. A dorsal root may be exhibited by the last spino-occipital nerve, though in most cases it is lacking. The arrangement of the cartilages in this region is somewhat irregular. When the dorsal root of z is present the hinder part of the skull is longer than usual, and, whilst z^v always passes through the skull, z^d issues through a separate intercalary cartilage. In other words, where there is least condensation in this region of the skull, the basidorsal cartilage corresponding with nerve z is fused with the cranium, whilst the interdorsal remains separate and transmits z^d if this be present. When z^d is absent the interdorsal may remain as a separate cartilage, or it may fuse with the basidorsal next behind it. An idea of the amount of variation in this region may be obtained from Figs. 4 and 5 on Plate I. The existence of such variations serves to greatly strengthen the theory of vertebral condensation, though the point with which we are here concerned is that they are not of sufficient magnitude to materially confuse the nomenclature of this region. The anterior limit of the whole vertebrae is capable of rigid demarcation.

The junction of the whole and half vertebrae is in most cases easily determined, and the two most rostral of the half vertebrae each show a basidorsal and an interdorsal cartilage on either side. Over the 1st, 3rd, 5th,... half vertebrae there are no nerve foramina; they occur only over the even-numbered half vertebrae. From this normal condition variations of two sorts occur. There may be only two pairs of cartilages over the first two half vertebral centra taken together (Fig. 6 *a*, Plate I), a very large basidorsal and a small interdorsal, which latter, as usual, affords a passage for the dorsal root. In fact, we have here a whole vertebra in which the centrum has become divided, without division of the cartilages forming the neural arch. For purposes of this paper, such a condition has to be reckoned as two half vertebrae. The second form of variation is an incomplete division of the centrum of the last whole vertebra. The division may be incipient only, or it may be fairly well marked on one side whilst absent on the other. In such cases, which are comparatively rare, the centrum exhibiting such incomplete division has been reckoned as that of the last whole vertebra.

2. *Half vertebrae.* The rostral limit of the half vertebrae has already been discussed. The caudal limit in *Spinax* is quite well defined, and little difficulty was experienced in deciding the number when the cleaned skeleton of the tail-fin was examined with a simple lens, though the higher powers of a dissecting microscope were used in the case of the embryos. It has been assumed that all the vertebrae, from the junction with the whole vertebrae to the tip of the tail, fall into the same category, viz. that of half vertebrae.

Ridewood (**'99**, p. 55) has recently disputed this on the ground that towards the caudal end the myotomes are twice as numerous as in the rostral part of the series. As this point is of great importance for the present paper I may here give the reasons which have led me to dissent from the view taken by Ridewood.

(a) On the hypothesis that the half vertebrae do not extend to the end of the tail, but that at some point the whole vertebral condition is resumed, one would naturally look for a transitional portion such as occurs more rostrally between the whole and half vertebrae. No such portion is however to be found. The centra of the half vertebrae become gradually and uniformly smaller till they cease.

(β) Occasional variations are to be met with in which an unusually long centrum occurs among the half vertebrae (cf. Plate I, Fig. 3). Such a variation is easily explicable on the assumption that it is a whole vertebra which has failed to split into two half vertebrae. Such centra I have reckoned as equivalent to two half vertebrae.

(γ) Ridewood states that in *Acanthias vulgaris* the transition from half vertebrae back to whole vertebrae occurs at about the 24th vertebra from the caudal extremity. This statement led me to examine the position of the spinal nerves in three specimens of this species. The last few segments have no spinal nerves issuing out from them but the attenuated myotomes in this region receive their innervation from nerves passing out more rostrally. By opening the neural canal and using osmic acid the minutest caudal roots were evident. Their mode of exit was uniform to their end, i.e. over every even-numbered half vertebral centrum. Counting gave the following results:

	Total number of half vertebrae	Last half vertebra over which a nerve root passes out
Specimen A ...	67	46
,, B ...	63	50
,, C ...	65	48

In these three cases there could not have been more than 21, 13, and 17 whole vertebrae respectively caudal to the half vertebrae, whilst from the arrangement of the myotomes Ridewood claims that there are 24. Taking all the evidence together, and admitting that the myotomes may show some difference of attachment at the end of the tail, there can, I think, be very little doubt but that the centra throughout the caudal region belong to the same class, viz. that of half vertebrae.

3. *Total segments.* The number of these was obtained by adding the number of the whole vertebrae to the number of the half vertebrae divided by two. Odd half vertebrae were counted as a whole segment, e.g. a specimen with 44 whole vertebrae and 41 half vertebrae was reckoned as possessing $44 + 21 = 65$ segments.

4. *Anterior spine.* The position of this was determined by a sagittal section. It articulates most commonly with the basidorsal and interdorsal cartilages of a single vertebra (Plate I, Fig. 1 *b*). In such cases it has been reckoned as belonging

to that vertebra. Sometimes it articulates with the interdorsal of vertebra x and the basidorsal of $x+1$ (Plate I, Fig. 1 *c*). In such cases it has been reckoned as belonging to segment x. Lastly, it may be carried mainly by a basidorsal, though to a slight extent by the interdorsals in front and behind (Plate I, Fig. 1 *a*). Here it has been regarded as pertaining to the segment to which the basidorsal belongs.

5. *Posterior spine.* A uniform system of nomenclature has been adopted throughout, and what applies to the anterior applies also to the posterior spine.

6. *1st girdle-piercing nerve* (*1st g. p. n.*). The pelvic girdle is pierced by one or two foramina transmitting certain of the ventral divisions of the fin-nerves. When only one foramen is present it transmits the ventral division of the nervus collector. When, as is less frequently the case, two foramina are found, the anterior of them transmits the collector. The most caudal of the nerves which go to form the collector therefore passes down almost directly to the foramen, and it is this, the 1st girdle-piercing nerve, that I have used to estimate the position of the pelvic girdle with reference to the axial skeleton.

7. *The nervus collector* contains in *Spinax* several branches lying along the lateral vein (cf. Braus, **'98**, Fig. 5, Plate XI). By injecting this vessel with osmic acid, in the way that I have previously described for *Mustelus* (**'00**, p. 332), the smallest branches can be readily made out.

8. As *post-girdle nerves* (*p. g. n.*), I designate all such as run to the fin on the caudal side of the 1st g. p. n. Thus, if there are two foramina in the pelvic girdle, the nerve passing through the hinder one will be the 1st post-girdle nerve. It not infrequently happens that the fin branch of the most caudal fin nerve joins with the fin branch of the most caudal but one before entering the fin, thus forming a "posterior collector"; more rarely the "posterior collector" may be composed of branches from three nerves. Such a condition is brought about by persistence of the early embryonic state of things in which a posterior collector is normally present, as Braus has already shown (**'02**, p. 566).

9. The *fin rays* were counted for the pelvic fins of a number of ♀s. A slight difficulty was introduced here by the fact that the last ray may be more or less fused with the distal part of the metapterygium. Whether it was more or less fused, or quite free, the last ray was always reckoned independently.

10. The *length of the whole and half vertebral series* was determined in a number of ♂s. The measurements were made from centrum to centrum.

The observations made upon the various above-mentioned characters were tabulated separately for adults and embryos, and again for each sex apart. For each of the series so obtained the mean and standard deviation were calculated together with the probable error in each instance. The results are given in full in the Appendix, Tables 12—19.

Sexual Dimorphism.

One of the most striking points brought out by these figures is a well-marked sexual dimorphism permeating all the meristic features investigated. This is well shown in Table 1, below, and equally for the embryos as for the adults. On looking down this table it will be noticed that the ♀ adults differ from the ♂s in possessing a greater number of whole vertebrae and total segments, as well as in the fact that both the anterior and posterior spines are more caudally situated. In all these cases, except that of the half vertebrae and collector nerves, the difference in the means of the two sexes is more than three times the probable

TABLE 1.

Comparison of the mean (M.) *and its probable error* (P. E. M.) *between the sexes and between embryos and adults of each sex.*

		♂ adults (100)	♂ embryos (145)	♀ adults (163)	♀ embryos (159)
Anterior spine	M.	15·979	15·965	16·159	16·056
	P. E. M.	± ·046	± ·031	± ·040	± ·031
Posterior spine	M.	40·540	40·476	41·170	40·686
	P. E. M.	± ·060	± ·051	± ·048	± ·040
Whole vertebrae... ...	M.	44·620	44·510	45·061	44·723
	P. E. M.	± ·077	± ·074	± ·057	± ·058
Half vertebrae	M.	40·370	40·034	40·288	39·956
	P. E. M.	± ·128	± ·107	± ·101	± ·091
Total segments	M.	65·040	64·724	65·472	64·906
	P. E. M.	± ·071	± ·065	± ·055	± ·056
First girdle-piercing nerve	M.	28·470	—	29·057	—
	P. E. M.	± ·041		± ·030	
Post-girdle nerves ...	M.	9·360	—	7·920	—
	P. E. M.	± ·039		± ·030	
Collector nerves	M.	5·230	—	5·304	—
	P. E. M.	± ·030		± ·024	

The question whether any two values of a statistical constant have a significant difference in value is to be settled by comparing that difference with the probable error of that difference, which by a well-known theorem in the theory of errors is the square root of the sum of the squares of the probable errors of the two given values. Professor Pearson to whom I am indebted for this statement considers odds less than those corresponding to twice the probable error as not definitely significant, with odds corresponding to twice up to thrice the probable error we have probable significance, and with more than three times the probable error there is almost certain significance. Of course a difference less than twice the probable error does not *prove* that the difference is insignificant, it may merely indicate that the statistics are insufficient in number to adequately distinguish significant differences. Again, persistent differences of the same sign, when each difference is even less than the probable error, increase the odds in favour of a general significance.

error of the difference, and is therefore doubtless significant. A comparison of these figures for the embryos reveals a similar condition of things with this small difference, viz. that the means of the two sexes are not quite so widely separated as in the adults. See Table 1 *bis*, p. 320. With regard to half vertebrae the ♂ embryos tend to show a rather larger number than the ♀s. The difference however is not so marked as in the features just considered, and falls within the limit of the probable error. Consequently, whilst it would be hazardous to attach much weight to this difference, yet the fact that it is found equally well marked in both embryos and adults lends some support to the view that it may not be altogether without significance.

In the cases of the 1st g. p. nerve and the post-girdle nerves, the differences in the means for the two sexes are so great that there can be no doubt but that we are here dealing with characters exhibiting a marked sexual dimorphism. The difference in the number of collector nerves is also nearly double the probable error of the difference and is therefore possibly significant.

The fact that for both cases the mean of the embryos is in all cases less than that of the adults, coupled with the fact that these differences are probably in every case significant, would seem to denote one of two things. Either selection has been at work during post-embryonic existence, and in such a way that the factors concerned have operated in the same direction for both sexes, or else an increase in the number of segments takes place during this period. But these are points to which reference will be made later.

The figures given in Table 1 show that a well-marked sexual dimorphism occurs, and that it cannot be due to selection, since it is almost equally apparent among the unborn young. Such sexual differences have been shown to exist also among other Elasmobranchs where considerable numbers have been examined, viz. in *Mustelus laevis* (**'00**, p. 339), and in *Acanthias vulgaris* (**'01**, p. 24). From which it follows that in attempting to trace ontogenetic changes from a numerical standpoint, this factor must be taken into account as well as the variability of these structures; and any attempt that neglects these factors must necessarily be of comparatively little value. It seems a plausible view that the sexual dimorphism which occurs in the Elasmobranchs is due primarily to the presence of the claspers which are found in the ♂. The enlargement of the distal part of the pelvic fin necessitated by the development of these structures has led to a more rostral position of the pelvic girdle, which in its turn involves correlated changes throughout the meristic series. If there be any truth in the view that the claspers are the determining cause of the meristic differences in the sexes, one would be led to expect no such difference among the Teleostei, where such organs are absent. The only member of that group which, so far as I am aware, has been examined in this connection is *Clupea harengus*. In his elaborate study of that fish, Heincke (**'98**, p. 95) has shown that there are no sexual differences with regard to the vertebrae or to the position of the fins, paired and unpaired.

*TABLE 1 *bis.*

Significance in Difference of Type.

Δ_{st} = difference of means of classes s and t.

$R = \Delta_{st}/\sqrt{\text{sum of squares of probable errors of means}}$.

Test of significance as on p. 318.

Character	♂ adult—♀ adult			♂ embryo—♀ embryo			♂ embryo—♂ adult			♀ embryo—♀ adult		
	Δ	R	Significance	Δ	R	Significance	Δ	R	Significance	Δ	R	Significance
Anterior spine	− ·180	− 3·0	Highly probable	− ·091	− 2·1	Probable	− ·014	− ·3	None	− ·103	− 2·0	Probable
Posterior spine	− ·630	− 8·2	Highly probable	− ·210	− 3·2	Highly probable	− ·064	− ·8	None	− ·484	− 7·7	Highly probable
Whole vertebrae ...	− ·441	− 4·6	Highly probable	− ·213	− 2·3	Probable	− ·110	− 1·0	None	− ·338	− 4·2	Highly probable
Half vertebrae	+ ·082	+ ·5	None	+ ·078	+ ·6	None	− ·336	− 2·0	Probable	− ·332	− 2·4	Probable
Total segments	− ·432	− 4·8	Highly probable	− ·182	− 2·1	Probable	− ·324	− 3·4	Highly probable	− ·566	− 7·2	Highly probable
1st girdle-piercing nerve	− ·587	− 11·6	Highly probable	—	—	—	—	—	—	—	—	—
Post-girdle nerves ...	+ 1·440	+ 29·3	Highly probable	—	—	—	—	—	—	—	—	—
Collector nerves ...	− ·074	− 1·9	Doubtful	—	—	—	—	—	—	—	—	—

It will be found that while the ♂ and ♀ differences are highly significant for both adults and embryos in all but one case, the differences between embryos and adults are more markedly significant for ♀s than ♂s. In the latter case, however, the signs are, as in the former, *all alike*, thus increasing the odds in favour of significance from the combined cases. The weighted mothers, while significantly different from the adult ♀s as far as variation is concerned (see p. 325) appear to be only significantly different in type for the case of half vertebrae.

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* [For this Table and for Tables 3 and 5 *c* I am indebted to Professor Pearson. R. C. P.]

The Numerical Proportions of the Sexes.

In connection with what has gone before a brief digression on the proportional numbers of the sexes may not be out of place. Storm's (**'80**) experience was that the ♂s of *Spinax* were rarer than the ♀s, though he gives no numbers. Records of the numbers of each sex caught off Ask have been made at different times by Braus, Nordgaard, and myself, and are given in the subjoined table.

	♂	♀
*Braus, July, 1897	121	98
Punnett, July, 1901	37	83
„ June-July, 1902 ...	47	65
Nordgaard, July, 1903	13	23
	218	269

The collected figures agree with Storm's conclusion, the only case where the ♂s were more numerous being Braus' experience in 1897. Braus also collected at Drobak, near Christiania, where he found that the ♂s were very much scarcer than the ♀s, being in fact only half as numerous. There are good grounds therefore for supposing that in the adult state the ♂s are less numerous than the ♀s. The sexes are, however, produced in practically equal numbers, for out of a total of 308† embryos were found 149 ♂s and 159 ♀s. And this conclusion is strengthened by the fact that in the three different years, 1901–3, in which embryos were collected, the proportion of ♂s to ♀s was respectively 35 : 39, 48 : 46, and 66 : 74. Consequently from a consideration of the proportional numbers of the sexes before birth and during adult life we are led to conclude that post-natal mortality is greater among the ♂s than among the ♀s. This conclusion is of considerable importance, for, as will appear below, statistical treatment of the meristic variations points independently in the same direction.

II. VARIATION AND CORRELATION.

Meristic Variability.

The measure of the variability used is the standard deviation (σ) which has been calculated separately for the adults and embryos, and for both sexes. The results are given in Table 2, and allow of a comparison between the sexes, for embryos as well as for adults. As there is some irregularity in this table a rough approximation to the variability has been made by taking the mean for the first

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[*] In his paper on *Spinax*, Professor Braus gave the proportion of ♂s to ♀s as 11 : 5 at Ask, and 5 : 6 at Drobak ('99, p. 421). In reply to a letter of mine Professor Braus explained how an error had crept into the MSS. on this point and very kindly sent me the actual figures which I have here made use of.

[†] Four of these ♂s do not figure in the Appendix Tables, as they were crippled and therefore useless from an anatomical point of view.

five characters given (i.e. the characters determined in both embryos and adults) in each instance. This gives the following figures :—

	Average value of σ for five characters
♂ adults	1·131
♂ embryos	1·174
♀ adults	1·132
♀ embryos	1·057

TABLE 2*.

Comparison of the Standard Deviation (σ) *and its Probable Error* (P. E. σ) *between the sexes, and between embryos and adults of each sex.*

		♂ adults (100)	♂ embryos (145)	♀ adults (163)	♀ embryos (159)
Anterior spine	σ	·670	·568	·721	·585
	P. E. σ	± ·032	± ·023	± ·028	± ·022
Posterior spine	σ	·888	·910	·906	·862
	P. E. σ	± ·042	± ·036	± ·034	± ·028
Whole vertebrae	σ	1·147	1·319	1·072	1·093
	P. E. σ	± ·055	± ·052	± ·040	± ·041
Half vertebrae	σ	1·901	1·917	1·921	1·702
	P. E. σ	± ·091	± ·076	± ·072	± ·064
Total segments	σ	1·048	1·154	1·041	1·045
	P. E. σ	± ·050	± ·046	± ·039	± ·039
First girdle-piercing nerve	σ	·871	—	·771	—
	P. E. σ	± ·029	—	± ·021	—
Post-girdle nerves... ...	σ	·819	—	·758	—
	P. E. σ	± ·028	—	± ·021	—
Collector nerves	σ	·630	—	·606	—
	P. E. σ	± ·021	—	± ·017	—

(1) *Comparison between the adults.* The ♀s appear to be somewhat more variable with regard to the position of the spines and also in the number of half vertebrae, though the difference in each case is not significant. For total segments the variability is almost the same in each sex. The ♂s are more variable for whole vertebrae though here again the difference is not really significant. The average variability is practically identical in each case (1·131 for ♂s and 1·132 for ♀s). For characters, however, which involve the position of the pelvic girdle and plexus the ♂s are somewhat more variable than the ♀s. In the case of the 1st g. p. n. the difference is more probably significant; it may be significant for the post-girdle nerves. The smaller difference in the collector nerves also points to greater ♂ variability. A comparison then of the variability in the adults only of each sex seems to point (*a*) to equality of variability for characters involving the spines and vertebral column, and (*β*) to greater variability

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* Sheppard's correction has not been used here.

TABLE 3.

Significance of Differences between Embryos and Adults, and between Males and Females.

Δ_{st} = difference of standard deviations of classes s and t.

$R = \Delta_{st}/\sqrt{\text{sum of squares of probable errors of standard deviations}}$.

Test of significance as on p. 318.

Character	♂ embryo—♂ adult			♀ embryo—♀ adult			♂ adult—♀ adult			♂ embryo—♀ embryo		
	Δ	R	Significance	Δ	R	Significance	Δ	R	Significance	Δ	R	Significance
Anterior spine	−·102	−2·6	Probable	−·136	−3·8	Highly probable	−·051	−1·2	None	−·017	−·5	None
Posterior spine	·022	·4	None	−·044	−1·0	None	−·018	−·3	None	+·048	+1·1	None
Whole vertebrae... ...	·172	2·3	Probable	·021	·4	None	+·075	+1·1	None	+·226	+3·4	Highly probable
Half vertebrae	·016	·1	None	−·219	−2·3	Probable	−·020	−·2	None	+·215	+2·2	Probable
Total segments	·106	1·6	None	·004	·1	None	+·007	+·1	None	+·109	+1·8	Doubtful
First girdle-piercing nerve	—	—	—	—	—	—	+·100	+2·8	Probable	—	—	—
Post-girdle nerves ...	—	—	—	—	—	—	+·061	+1·7	Doubtful	—	—	—
Collector nerves	—	—	—	—	—	—	+·024	+·9	None	—	—	—

There are thus six characters in which the embryos are more variable than the adults and four in which they are less variable. There are only four in which this difference in variability is probably significant. This significant difference, since the above adults are not the parents of the embryos, may be due to the actual parents being a small selection from the general population. We can only test this in the case of mothers ; we then find no significant difference between weighted mothers and actual offspring in the half vertebrae, but a still more significant difference in the anterior spine. Hence it would seem certain that the adults are *more* variable than the embryos in the position of the anterior spine in the case of both sexes. Whether the ♂ embryos are really more variable than the adults in whole vertebrae can hardly be settled from the data.

There are four out of thirteen characters in which the ♀s are more variable than the ♂s, but in no one of these is the difference really significant. There are nine cases in which the ♂s are more variable than the ♀s ; in one of these, whole vertebrae, the difference is almost certainly significant for embryos, it is probably significant in half vertebrae for embryos and in first girdle-piercing nerve for adults. In the other cases it is twice hardly significant and four times certainly not significant.

on the part of the ♂s for characters connected with the position of the pelvic fins. See Table 3, p. 323.

(2) *Comparison for embryos.* It has been seen above that the average variability for the five characters taken is much greater for ♂ than for ♀ embryos (1·174 to 1·057). The ♀ embryos show a greater variability for the anterior spine but for all the four remaining characters the ♂s are more variable, and in the cases of whole and half vertebrae (and possibly total segments) the differences are so great in comparison with the probable errors of the differences as to leave little doubt but that they are significant. See Tables 3 and 3 *a*.

(3) *Comparison of embryos with adults.* It has been seen that the average variability is greater for the embryos than for the adults in the case of the ♂s (1·174 to 1·131) and less in the case of the ♀s (1·057 to 1·132). The variability for the different characters is somewhat irregular, but there is a striking agreement between the way in which on the one hand the ♂ embryos differ from the ♂ adults, and the way in which on the other hand the ♀ embryos differ from the ♀ adults. This may be expressed by saying that (*a*) where the ♂ embryos are less variable than the ♂ adults, the ♀ embryos will be less variable than the ♀ adults and to a greater degree; (β) where the ♂ embryos and adults are equally variable the ♀ embryos will be less variable than the ♀ adults; and (γ) where the ♂ embryos are more variable than the ♂ adults, the ♀ embryos and adults will be equally variable. This point is exemplified in the subjoined table, which gives roughly the comparative variability of the embryos and adults in each sex.

TABLE 3 *a*.

+ signifies that the embryos are more variable than the adults.
– ,, ,, less ,, ,,
[ ] signifies that the difference in variability is small and lies within the mean of the probable errors for embryos and adults, i.e. that there is in such cases practically equality of variability.

Comparative variability of	♂ embryo to ♂ adult	♀ embryo to ♀ adult	Amount by which ♂ embryos are more variable than ♀ embryos
Anterior spine ...	– by 3 P. E.*	– by 5½ P. E.	– 2½ P. E.
Posterior spine ...	[+] ,, ½ P. E.	– ,, 1½ P. E.	2 P. E.
Whole vertebrae ...	+ ,, 3 P. E.	[+] ,, ½ P. E.	2½ P. E.
Half vertebrae ...	[+] ,, ⅕ P. E.	– ,, 3 P. E.	3 P. E.
Total segments ...	+ ,, 2 P. E.	[+] ,, ⅒ P. E.	2 P. E.

Hence the ♂ embryos as compared with the ♂ adults show a relatively higher variability throughout (except for the anterior spine) than do the ♀ embryos as compared with the ♀ adults. Again, while the ♂ embryos are absolutely more variable than the ♂ adults, the ♀ embryos are absolutely less variable than the

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* P. E. here signifies the mean of the two probable errors, i.e. that for embryos and that for adults.

♀ adults. If we suppose the groups of embryos and adults with which we are dealing to be fair samples of the whole population, and there seems no valid reason for any assumption to the contrary*, then it is to some such process as the following that we must look for an explanation. We must suppose that higher variability is an attribute of the ♂, but that, owing to some subsequent process of selection in this sex the variability of adult ♂s is brought down to equality with that found among adult ♀s. This, however, will not serve to explain the lessened variability of ♀ embryos as compared with ♀ adults. It is possible that these differences are due to unconscious selection of the embryonic material which is the product of not more than 40 mothers. On *a priori* grounds it is therefore most unlikely that this relatively small number of mothers is truly representative of mothers as a whole. To test this point the variability of ♀ offspring of known mothers was calculated and compared with the variability of the weighted mothers, and the results given in the following table:—

TABLE 4.

	σ for ♀ embryos ($N=115$)	σ for weighted mothers (Actual No. = 25)
Anterior spine ...	·6242	·6665
Posterior spine ...	·7447	·6715
Whole vertebrae ...	·9921	·8192
Half vertebrae ...	1·5920	1·7358
Total segments ...	·9903	1·0495
Average ...	·9987	·9885

Hence when there is identical selection of material the average variability of ♀ embryos and ♀ adults is also identical. It is therefore exceedingly likely that the comparatively low variability of ♀ embryos as a whole as compared with ♀ adults as a whole is due to the fact that the ♀ parents were here unconsciously selected. There is every reason to suppose that such a diminution of embryonic variability as the result of unconscious selection obtains equally among the ♂ embryos. The average variability of the ♂ embryos should therefore be appreciably greater than the figure (1·174) already given, thus accentuating the phenomenon of greater variability among ♂ embryos as compared with ♂ adults.

In summing up briefly what is to be learnt from a comparison of the variability of ♂s and ♀s, embryos and adults, it may be tentatively stated that the average variability of ♀ embryos and of adults of both sexes is practically identical, whilst the variability of ♂ embryos is considerably greater. From which follows the

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[* The variability of the weighted mothers is in one case equal to that of the adult ♀s. In the four other cases it is less, and in three of them—posterior spine, whole vertebrae and half vertebrae—very significantly less than that of adult ♀s. K. P.]

conclusion that some process of selection takes place among the ♂s during post-natal existence, leading to a reduction of their variability to the amount exhibited by the unselected ♀s. And this conclusion is in accordance with the fact that, whilst the two sexes are produced in equal numbers, the adult ♂s are less numerous than the adult ♀s. (Cf. p. 321.)

Variability in different Regions.

That considerable differences in variability, as measured by the standard deviation, obtain for various regions of the vertebral series has already become apparent. As, however, the number of meristic units which goes to make up these different regions differs widely, their relative variability must be compared by means of the coefficient of variability $\left(=\frac{100\,\sigma}{M}\right)$. These values are given in Table 5 *a*, from which it appears that the variability shows wide differences according to the character chosen—differences on the whole equally well marked in the four groups of embryos and adults. The existence of such differences is antagonistic to the conception of the landmarks along the vertebral series being associated with particular vertebrae, and depending for their various positions on any uniform process of augmentation or reduction taking place in that series. To this point however reference will be made later on (pp. 335–6).

TABLE 5 *a*.

Coefficients of Variation.

	♂ adults	♂ embryos	♀ adults	♀ embryos
Anterior spine ...	4·19	3·47	4·46	3·65
Posterior spine ...	2·19	2·24	2·20	2 12
Whole vertebrae ...	2·57	2·96	2·38	2·44
Half vertebrae ...	4·71	4·79	4·77	4·26
Total segments ...	1·61	1·78	1·59	1·61

Correlated Variability in the Meristic Series.

With the idea of attempting to throw some light on the processes at work in the vertebral column, the various characters have been correlated with one another. This has been done separately for the two sexes, as well as for embryos and adults apart. The results given in Table 5 *b* show that there is on the whole considerable agreement in the four groups of material. Where the correlation value between two characters is high for one group it usually exhibits a similar high value for the other three groups, and *vice versâ*. Certain marked discrepancies however are to be found, notably (*a*) between embryos and adults for the correlation of the anterior with the posterior spine; (*β*) between the ♂ embryos and the other three groups for the correlation between total segments and half vertebrae; and (*γ*) between ♀ adults and the rest for the correlation of anterior spine with total segments. Certain of these discrepancies will be referred to later in connection with growth changes (p. 333). Meanwhile some more or less definite conclusions may be drawn from the table of correlation values.

TABLE 5*b**.

Correlation Values.

	♂ adults	♂ embryos	♀ adults	♀ embryos
Whole vertebrae and posterior spine	·7317 ± ·0304	·7742 ± ·0218	·6540 ± ·0297	·7218 ± ·0248
Total segments and posterior spine	·6753 ± ·0356	·6832 ± ·0290	·6754 ± ·0282	·5882 ± ·0316
Total segments and whole vertebrae	·5534 ± ·0454	·6707 ± ·0299	·5660 ± ·0348	·6492 ± ·0300
Whole vertebrae and half vertebrae	− ·5226 ± ·0476	− ·5580 ± ·0374	− ·4859 ± ·0392	− ·5028 ± ·0388
Anterior spine and posterior spine	·5216 ± ·0485	·2102 ± ·0524	·4828 ± ·0420	·2719 ± ·0485
Total segments and half vertebrae	·3745 ± ·0563	·1945 ± ·0523	·4397 ± ·0414	·3266 ± ·0464
Total segments and anterior spine	·1544 ± ·0645	·1684 ± ·0528	·3279 ± ·0485	·2246 ± ·0493
Anterior spine and half vertebrae	− ·1998 ± ·0635	·0009 ± ·0543	·0031 ± ·0542	− ·068 ± ·0517
First girdle-piercing nerve and post-girdle nerves	− ·6227 ± ·0283	—	− ·5758 ± ·0254	—
First girdle-piercing nerve and posterior spine	·5768 ± ·0309	—	·5398 ± ·0270	—
First girdle-piercing nerve and whole vertebrae	·6181 ± ·0286	—	·4548 ± ·0302	—
First girdle-piercing nerve and collector nerves	·5590 ± ·0318	—	·3821 ± ·0325	—
First girdle-piercing nerve and total segments .	·5051 ± ·0345	—	·4253 ± ·0312	—
Total segments and collector nerves	·2056 ± ·0443	—	·102 ± ·0376	—
No. of fin rays and pelvic nerves	—	—	·058 ± ·0680	—
No. and proportional length of whole vertebrae	·5838 ± ·0582	—	—	—

(1) The correlation of each of the various characters chosen with the total number of segments differs very considerably. Thus, for the posterior spine and for the whole vertebrae it is on the average ·66 and ·61 respectively—for the anterior spine and for the half vertebrae only ·23 and ·33. To take the case of

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* Sheppard's correction has not been used here.

TABLE 5 *c*.

Significance of Differences in Correlation Values.

Δ_{st} = Difference between correlations for classes s and t.

$R = \Delta_{st}/\sqrt{\text{sum of squares of probable errors of correlations}}$.

Test of significance as on p. 318.

Pair of characters correlated	♂ adult— ♀ adult			♂ embryo— ♀ embryo			♂ adult— ♂ embryo			♀ adult— ♀ embryo		
	Δ	R	Significance	Δ	R	Significance	Δ	R	Significance	Δ	R	Significance
Whole vertebrae and posterior spine ...	+·078	+1·8	Doubtful	+·052	+1·6	None	+·043	+1·1	None	+·068	+1·7	Doubtful
Total segments and posterior spine ...	–·000	– ·0	None	+·095	+2·2	Probable	+·008	+ ·2	None	–·087	–2·1	Probable
Total segments and whole vertebrae ...	–·013	– ·2	None	+·022	+ ·5	None	+·117	+2·2	Probable	+·083	+1·8	Doubtful
Whole vertebrae and half vertebrae ...	–·037	– ·6	None	–·055	–1·0	None	–·035	– ·6	None	–·017	– ·3	None
Anterior spine and posterior spine ...	+·039	+ ·6	None	–·062	– ·9	None	–·311	–4·4	Highly probable	–·211	–3·3	Highly probable
Total segments and half vertebrae ...	–·065	– ·9	None	–·132	+1·9	Doubtful	–·180	–2·3	Probable	–·113	–1·8	Doubtful
Total segments and anterior spine ...	–·174	–2·2	Probable	–·056	– ·8	None	+·04	+ ·2	None	–·103	–1·5	None
Anterior spine and half vertebrae ...	–·203	–2·4	Probable	+·069	+ ·9	None	+·201	+2·4	Probable	–·071	– ·9	None
1st girdle-piercing n. and post-girdle nerves	–·045	–1·2	None	—	—	—	—	—	—	—	—	—
1st girdle-piercing n. and posterior spine	+·037	+ ·9	None	—	—	—	—	—	—	—	—	—
1st girdle-piercing n. and whole vertebrae	+·163	+3·9	Highly probable	—	—	—	—	—	—	—	—	—
1st girdle-piercing n. and collector nerves	+·177	+3·8	Highly probable	—	—	—	—	—	—	—	—	—
1st girdle-piercing n. and total segments	+·080	+1·7	None	—	—	—	—	—	—	—	—	—
Total segments and collector nerves ...	+·104	+1·8	Doubtful	—	—	—	—	—	—	—	—	—

This table shows that sexual difference is only significant in five out of the twenty-two cases dealt with. Of these five, it is 'probable' in three and 'highly probable' in two. There is sensibly no difference in correlation between the embryos of the two sexes, and the most important cases of the adults are those for the first girdle-piercing nerve with the whole vertebrae and with the collector nerves, cases for which we have not data for the embryos. There appear to be markedly significant differences for both sexes between adults and embryos in the correlation between posterior and anterior spines, the correlation intensifying with age. There are three other cases of probable significance in the male, and one only in the female, although in the latter sex the correlations increase with age in six out of the eight cases.

the two spines—the fact that the average correlation with the total number of segments is nearly three times as great for the posterior as for the anterior would seem to point conclusively to dissimilarity in the factors determining their position*. Certainly they cannot owe their various positions to some uniform process of shortening or lengthening of the vertebral column alone†. Probably one must regard the spines as structures showing oscillations from a mean position backwards and forwards along the vertebral column. These oscillations are relatively greater in the anterior spine (where the C.V. is about 4), and are more independent of the total number of segments because there are no specialized structures in close proximity tending to fix its position. Consequently the correlation with the total number of segments is small. The posterior spine on the other hand occurs in the region of the pelvic fins and of the junction of the whole with the half vertebrae. With the number of the whole vertebrae, and with the position of the pelvics as estimated by the 1st g. p. nerve, it is highly correlated (the average values of these correlations being about ·72 and ·55 respectively). The coefficient of variability for the posterior spine is smaller than that for the anterior, which is probably to be explained by the fact that the high correlations alluded to tend to limit the oscillations of the former structure· These high correlation values force us to conclude that the three structures concerned vary very much in sympathy with one another. The fact that the position of the posterior spine is largely dependent on the number of whole vertebrae and on the position of the pelvic fins must lead us to suppose that its independent oscillations are to a great extent checked, a view that is borne out by the relatively low variability (average C.V. = 2·19) of this spine as compared with that of the anterior. Moreover, the intimate relation of the posterior spine with the whole vertebrae serves to explain its high correlation with the total number of segments. For the number of the whole vertebrae is largely dependent on the total number of segments, as the average correlation value ·61 shows. To sum up, the position of the spines was probably in the first place largely independent of the total number of segments, and, where no further complications are introduced, remains so, as in the case of the anterior spine. When, however, the spine enters into close relation with other structures whose position is largely dependent on the total number of segments, its variability becomes checked and the value of its correlation with the last-named feature increased.

(2) As the vertebral column is composed partly of whole and partly of half vertebrae, one would expect any change in the total number of meristic units to affect both of these regions. This is the case, though not to an equal extent in each. A high correlation exists between total segments and whole vertebrae—a considerably lower one between total segments and half vertebrae. Whilst the

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* On the hypothesis of random interpolation the ratio of these correlations should be the ratio of the standard deviation of the posterior spine to anterior spine, or on the average ·892 to ·636, i.e. rather as 3 to 2, than the observed 3 to 1.

† Nor to random interpolation.

number of whole vertebrae, the meristic units characteristic of the trunk region, is largely governed by the total number of segments (average correlation = ·61), the number of the more variable half vertebrae constituting the caudal region is far less dependent upon this factor (average correlation = ·33). From this difference* it must be inferred that the influence of any factor leading to an increase or decrease in the total meristic series will not be equally exhibited in the change in number of the whole and of the half vertebrae. Thus, reduction of the total segments will be accompanied by a marked reduction in the number of whole vertebrae, and by a much smaller one in the number of half vertebrae. Hence, the result of increasing reduction of the total number of segments, and consequently of the whole vertebrae, must be to increase the ratio $\frac{\text{number of half vertebrae}}{\text{number of whole vertebrae}}$. That such is actually the case is strikingly brought out on correlating the numbers of the half and whole vertebrae. The correlation value (Table 5 *b*) is fairly high (average = ·52) and is *negative*. In other words, the greater the number of whole vertebrae the *relatively* smaller is the number of half vertebrae associated with them. Elsewhere (p. 334) reasons are given for supposing that a gradual reduction in the number of segments is in process phylogenetically. The above facts would lead one to suppose that this is being brought about by reduction of the whole vertebrae, owing to their transformation into half vertebrae, and the variations already observed (p. 315) at the point of junction lend colour to this view. At the same time the number of half vertebrae is being reduced caudally but recruited, though to a somewhat less extent, rostrally from the whole vertebrae. Were the reduction in the number of whole vertebrae to keep pace with the reduction in the total number of segments, the correlation between these two characters would be unity. The number of half vertebrae would however be recruited by an increased amount, and its correlation with the total number of segments correspondingly reduced. Hence, on this view we should be led to expect that the higher is the correlation between the whole vertebrae and total segments, the lower will it be between the total segments and half vertebrae. If we consider the sexes separately this expectation is borne out by the actual numbers. Table 5 *b* shows that the correlation between whole vertebrae and total segments is slightly higher in the embryos of each sex than in the corresponding adults, whilst at the same time the corre-

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* The extent to which the whole and half vertebrae respectively would be affected by a change in the total number of segments is more correctly given by the coefficient of regression of either of these two characters on the total number of segments. Thus the value of the regression of whole vertebrae on the total segments is given by the expression $\frac{\sigma \text{ for whole vertebrae}}{\sigma \text{ for total segments}} \times$ correlation between whole vertebrae and total segments. In the case of adult ♂s this is $\frac{1·147}{1·048} \times ·553 = ·602$. Similarly the value of the regression of half vertebrae on total segments is $\frac{1·002}{1·048} \times ·375 = ·353$. These two values show clearly that any change in the number of the total segments affects the whole vertebrae much more than the half vertebrae. (The value of σ for half vertebrae is 1·901 (Table 2) but this must be first translated into terms of total segments (cf. App. Table 27) which gives the above value 1·002.)

lation between total segments and half vertebrae is considerably lower in the embryos (cf. p. 327)*.

(3) The position of the pelvic fin (as determined by the 1st g. p. nerve) is in either sex fairly highly correlated with the posterior spine, the number of whole vertebrae, and the total number of segments. The value of the last correlation (average = ·46) is however sufficiently low to show that the position of this fin cannot be entirely due to any uniform process of reduction or increase in the meristic series. It has already been seen that, of the total fin innervation, part—the collector—is rostral to the pelvic girdle, and part—the post-girdle nerves—is caudal to that structure. On the supposition that the girdle is, so to speak, in a state of oscillation (exhibiting either backward or forward homoeosis, but especially the former), we should be led to look for evidence of such oscillation in the values of the correlations between these two sets of nerves and the position of the 1st g. p. nerve. We should expect an oscillation resulting in a more rostral position of the girdle to be accompanied by a diminution in the number of the collector branches and an increase in the number of the post-girdle nerves. This expectation is fully borne out by the correlations. That between the 1st g. p. nerve and the post-girdle nerves is high (– ·62 for ♂s and – ·57 for ♀s) and is *negative.* The smaller the number denoting the 1st g. p. nerve (i.e. the more rostral the

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[* It may be of slight interest to consider the topic of this paragraph from a rather more mathematical aspect.

The average correlation between whole vertebrae and total segments is ·610 and between half vertebrae (in whole vertebrae as units) is ·334. The mean standard deviation of total segments is 1·072, of whole vertebrae 1·158, and of half vertebrae (in whole vertebrae as units) is 1·096. Hence forming the regression coefficients:

$$\frac{\text{S. D. for whole vertebrae}}{\text{S. D. for total segments}} \times \text{correlation } {\cdot}610, \text{ and } \frac{\text{S. D. for half vertebrae}}{\text{S. D. for total segments}} \times \text{correlation } {\cdot}334,$$

we see that on the average an increase of one in the total segments will be accompanied by an increase of ·66 in the whole vertebrae and an increase of ·34 in the half vertebrae (measured in whole vertebrae as units). In other words one new whole vertebra is as likely to appear as one new half vertebra (measured as a half vertebra). But the total number of whole vertebrae is about double (44·6 to 20·4) the number of half vertebrae (in whole vertebra units); in other words the effect of increasing or decreasing the total segments is relatively to the whole and half vertebrae sensibly the same as adding or subtracting a vertebra anywhere at random, because the total number of whole vertebrae is roughly twice as great as the half vertebral series measured in the same unit, the whole vertebra.

Let w = whole vertebrae, h = half vertebrae (measured in whole as units), t = total segments, r = correlation coefficient. Then if the total number of segments were constant, since the standard deviations of whole and half vertebrae are approximately equal, we should expect that the expression for partial correlation, i.e.

$$\frac{r_{wh} - r_{wt}r_{ht}}{\sqrt{(1 - r^2_{wt})(1 - r^2_{ht})}},$$

should be closely equal to minus unity, for when the whole vertebrae lose one the half vertebrae must gain one. Equating the above expression to -1, and noting that $r_{wt} = {\cdot}610$ and $r_{ht} = {\cdot}334$ nearly, we find $r_{wh} = -{\cdot}54$, the average observed value of r_{wh} is $-{\cdot}52$—a very close result. In other words the correlation of whole and half vertebrae is what we might reasonably expect its value to be, the correlations for the two parts with the total being as above. In general terms the result is the same as if 50 per cent. of gain or loss of either whole or half vertebral series came from increase of total segments and 50 per cent. from a transfer from one series to the other. K. P.]

position of the girdle), the larger the number of post-girdle nerves associated with that position.

A considerable discrepancy will be noticed in the two sexes for the value of the correlation between the 1st g. p. n. and the collector nerves. The explanation is probably somewhat as follows. It has been shown by Braus (**'01**, p. 620) that the number of collector nerves in *Spinax* is greater during earlier than in subsequent stages of development. Even in early stages this rostral extension of the collector area has its limits. It is natural to suppose that with forward shifting of the girdle the more rostral of these branches will persist as the rostral part of the nervus collector. As however no nerve whose serial number is less than 21 seems to take part in the formation of the collector during early stages, any marked backward homoeosis in the pelvic area will be associated with a correspondingly marked reduction of the collector nerves. As the girdle shifts forwards the reduction in the number of collector branches will become disproportionately greater. Consequently, where the rostral pelvic shifting is less, we should expect to find a smaller correlation between the 1st g. p. nerve and the collector nerves. And this is actually what takes place. The ♀s, with their more caudally situated pelvics and greater average number of collector nerves, show a correlation value of only ·38, whilst that for the ♂s, where the girdle is more rostrally placed and the number of collector nerves somewhat fewer, amounts to ·55.

(4) It will be noticed in Table 5 *b* that certain correlation values are very low. This is the case for those between the anterior spine and half vertebrae, between the total number of segments and the collector nerves, and between the fin rays and the pelvic nerves. On the hypothesis that some uniform process of excalation is going on the mean correlations for the above characters ought not to differ greatly from the mean of the rest, which is somewhere between ·5 and ·6. Especially should there be a high correlation between the number of fin rays and the fin nerves. On the side-fold theory of limb origin the morphological connection between these structures is so intimate that a high correlation between the two would naturally be looked for, and the fact that there is practically no correlation whatever tells strongly against this theory. Moreover the little that is known on this head for *Acanthias*, the only other Elasmobranch similarly investigated (**'01**, p. 13), is in accordance with the foregoing facts.

(5) A well-marked correlation exists between the number of the whole vertebrae and their total length relative to the whole vertebral column. As will be seen (in Appendix, Table 36) the length of the series of whole vertebrae varies between ·605 and ·695 of the whole vertebral column. The range is consequently ·09, i.e. about 1/7·5 of the length of the series, whilst the range for the number of whole vertebrae is 6 in a series of 48, i.e. $\frac{1}{8}$. The range of variation in respect of length therefore bears approximately the same relation to the relative length as the range for number does to the total number of whole vertebrae. The value of the correlation is fairly high but should be very much closer to unity if the number is entirely dependent upon the length.

Growth Changes.

Note was made above (p. 327) of certain marked discrepancies in the correlation values.

(1) The correlation between anterior and posterior spines is much lower in embryos than in adults. Both anterior and posterior spines are rather more rostrally situated in the embryos than in the adults. The differences, however, in the ♂s are small and will not serve to explain the very low correlation values of the embryos. Again the variability of the posterior spine is very close in all the groups. When, however, the variability of the anterior spine is examined it is at once evident that its value is much less for the embryos than for the adults. It would appear not unlikely that changes in the position of this spine occur during post-natal growth. As these changes are in the direction of higher correlation with a more variable structure, the posterior spine (as estimated by σ), they must lead to greater variability in the anterior spine. Such is actually the case. Consequently we must suppose that the anterior spine is subject to a certain amount of change in position during growth. And in this connection it is interesting to notice that greater variability is associated with higher correlation also in the case of the characters involving the pelvic nerves of the ♂s as compared with the ♀s (cf. Tables 2 and 30—35).

(2) The correlation between the total segments and the half vertebrae for ♂ embryos is very low. The correlation between the total segments and whole vertebrae in this same group is however markedly higher than in the rest. Here again it is probable that growth changes come in. If during post-embryonic life we suppose that there is a certain amount of transformation of whole vertebrae into half vertebrae, such a process would lead to a reduction in the value of the correlation between whole vertebrae and total segments and an increase in the value of the correlation between total segments and half vertebrae. This is actually what has come about in the adult ♂s. Moreover the correlation values bear out the supposition that the same process occurs, though to a less extent, among the ♀s. The correlation between the half vertebrae and total segments is less in the embryos than in the adults, whilst that between the whole vertebrae and the total segments is greater. It is therefore exceedingly probable that a certain amount of conversion of whole into half vertebrae occurs in either sex during post-natal existence.

Variability in the Girdle Canals.

That there may be either one or two canals in the pelvic girdle for the transmission of nerves has already been noted. The figures below seem to show without doubt that the number of the canals is connected with the position of the girdle.

		No. of cases *	Mean position of girdle
♂	1 canal	110	28·69
	2 canals	86	28·17
		Difference	·52
♀	1 canal	184	29·17
	2 canals	112	28·86
		Difference	·31

The possession of two canals is associated with a markedly more rostral position of the girdle, the difference being half a metamere for the ♂s and a third of one in the case of the ♀s. Now it has already appeared that the pelvic girdle is more rostrally situated in the ♂ than in the ♀. Consequently we should be led to expect a larger proportion of fish with two canals among the ♂s, and this condition is what actually obtains. The $\frac{\text{no. of ♂s with 2 canals}}{\text{no. of ♂s with 1 canal}}$ is $\frac{86}{114}=\frac{78\cdot2}{100}$, whilst the $\frac{\text{no. of ♀s with 2 canals}}{\text{no. of ♀s with 1 canal}}$ is $\frac{112}{184}=\frac{60\cdot9}{100}$, cases of two canals being distinctly more numerous among the ♂s. Reasons have already been given (p. 331–2) for supposing that the different positions of the pelvic girdle are, at any rate in the main, due to a process of homoeosis, and that such homoeosis is for the most part backward homoeosis (cf. Bateson, **'94**, pp. 111 *et seq.*). Now the preponderance of two canals among the more rostrally situated girdles is explicable on the supposition that this homoeosis is in some measure ontogenetic. The "Anlage" of the girdle is relatively larger than its ultimate condition. Its width is somewhat greater than the interval between two successive limb nerves, some one of which it must necessarily enclose. Supposing then that rostral migration of the girdle occurs, that structure will at first abut against and ultimately enclose the nerve immediately anterior to it, whilst at the same time retaining as it were its grasp of the nerve which orginally perforated it. That some such process does actually occur is rendered probable by the observations of Braus (**'01**, p. 590 and Taf. XXIII, Fig. 8) on the arrangement of the cartilage cells. Hence the variations in the number of the girdle canals support the view that the different positions of the girdle are largely due to homoeosis, and that such homoeosis is to some extent ontogenetic, though this is probably confined to the earlier stages of development.

The Hypothesis of Excalation.

In most linear meristic series certain members become specialized in a definite manner and acquire thereby an individuality that serves to distinguish them from the rest of the series. In *Spinax* such specialization occurs in the case of those vertebrae which enter into a definite relation with the fins, paired and unpaired. On the hypothesis under consideration it is supposed that such specialized

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* As the number of canals may differ on the two sides of the same animal each side has been considered separately as a "case."

structural peculiarities become as it were the fixed attribute of certain particular segments. Thus in *Spinax* the vertebra that carries the anterior spine is to be regarded as strictly homologous in different specimens. The serial position of such a segment may vary in different individuals—in one it may be the *n*th, in another the $(n+1)$th, &c. On the hypothesis of excalation it is supposed that creatures such as *Spinax* have been derived from forms with a larger number of segments and that the various positions of the segments with a marked individuality are due to a uniform process of shortening up owing to the vertebral column splitting into a lessened number of parts. The amount of change in position in the specialized segment depends partly on the amount of reduction or excalation in the meristic series of which it is a member, and partly on its original position in that series. As a simple illustration we may take the case of a series consisting of 40 segments, the 10th and 20th of which are specialized, let us say by bearing spines. If we suppose the series to be reduced to 36 segments by a uniform process it is obvious that the spine-bearing segments will now be the 9th and 18th. Reduction of the whole series to the extent of four segments implies a change in position of the anterior spine to the extent of one segment, and in the posterior spine of two segments. In other words, the nearer to the middle of the series the specialized segment lies the greater is the change in its position involved by reduction in the number of the whole series. On the excalation hypothesis we are led to expect (1) a positive correlation between each specialized segment and the total number of the meristic series, and (2) approximate equality in the value of these correlations. Reference to Table 5 *b*, p. 327, shows that the former of these expectations is fulfilled. The value of the correlation between posterior spine and total segments is however very much greater than that between total segments and anterior spine, whilst the value of the correlation between another specialized segment, that of the 1st g. p. nerve, and the total number of segments is intermediate. Such facts throw considerable doubt on the possibility of symbolizing the facts by the excalation theory and the following considerations serve to emphasize that doubt.

TABLE 6 *a*.

A. *Posterior Spine.*

Number of segments ...	62	63	64	65	66	67	68
Number of specimens ...	2	26	91	158	81	33	5
Calculated values for position of posterior spine	38·9	39·6	40·2	40·8	41·4	42·1	42·8

The mean calculated position of posterior spine is **40·8** and is associated with 65 segments, which is the mean of the total number of segments. The standard deviation for the posterior spine (calculated position) works out to ± **·678**.

Observed values for position of posterior spine :

	38	39	40	41	42	43	44
Number of specimens ...	1	21	124	156	81	11	2

Mean position = **40·8**, $\sigma = \pm$ **·942**.

TABLE 6 *b*.

B. *Anterior Spine.*

Number of segments ...	63	64	65	66	67	68
Number of specimens ...	8	58	140	113	52	9
Calculated values for position of anterior spine	15·5	15·75	16	16·25	16·5	16·75

Then $\sigma = \pm$ ·284.

Observed values for position of anterior spine:

	14	15	16	17	18
Number of specimens ...	2	56	256	60	6

Whence $\sigma = \pm$ ·624.

TABLE 6 *c*.

C. *First girdle-piercing Nerve.*

♀s (296)

Number of segments ...	63	64	65	66	67	68
Number of specimens ...	4	44	120	80	42	8
Calculated values for position of first girdle-piercing nerve	27·89	28·34	28·78	29·22	29·66	30·11

Mean number of segments = **65·5**; mean of first girdle-piercing nerve = **29·0**.

Whence $\sigma = \pm$ ·461.

Whilst observed value of $\sigma = \pm$ ·760.

♂s (168)

Number of segments ...	63	64	65	66	67	68
Number of specimens ...	10	38	74	30	14	2
Calculated values for position of first girdle-piercing nerve	27·62	28·06	28·50	28·94	29·38	29·82

Mean number of segments = **65·0**; mean of first girdle-piercing nerve = **28·5**.

Whence $\sigma = \pm$ ·458.

Whilst observed value of $\sigma = \pm$ ·879.

If a number of specimens of *Spinax* are taken, in each of which the number of total segments is known, we may, knowing also the mean number of total segments and the mean position of the posterior spine, calculate the theoretical value of the variability (σ) of the posterior spine on this hypothesis. This has been done for the characters anterior and posterior spine and 1st g. p. nerve in ♂s as well as ♀s, and the results are given in Table 6*. For the posterior spine this theoretical value works out to ± ·678, which is considerably less than the observed value ± ·942. The variability of the posterior spine is actually much greater than it should be on the excalation hypothesis. This is also true for the anterior spine where the observed value, ± ·624, is very much greater than the calculated value ± ·284. The same is also true for the 1st g. p. nerve where the calculated values

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* These correlations were worked out in 1902 on the material collected in 1901 and 1902. It has been thought unnecessary to recalculate these figures by incorporating the material collected in 1903. The differences that would be introduced into the above values would probably be very slight.

± ·458 and ± ·461 for ♂s and ♀s respectively fall much below the observed values ± ·879 and ± ·760. It is therefore evident that the hypothesis of excalation will not serve to account for the magnitude of the observed variability.

On Intercalation.

By some morphologists (cf. Baur, '**97**, p. 52) it has been held that intercalation of segments as well as excalation may go on in a linear meristic series. To take the case of a portion of a vertebral column between two specialized and homologous segments, there are often to be found individuals exhibiting either a less or a greater number of segments than the normal. The former condition we are called upon to regard as the result of excalation, the latter as being due to intercalation; and to account for variations any such demarcated region of the segmented series must be held capable of undergoing intercalation in one specimen and excalation in another. In order to test this possibility we may consider the case of that portion of the vertebral column which lies between two highly specialized segments, viz. the segment whose nerve is the most rostral of those piercing the girdle, and the segment which carries the posterior spine. This division of the vertebral column consists of some 10—14 segments, of which the greater number (nearly three-quarters) are characterized by the fact that their spinal nerves send off branches to the pelvic fin. Now if the variations in the number of these 10—14 segments are due to intercalation and excalation we should expect the variations of those of them which supply the fin muscles to be in sympathy. In other words we should look for a high correlation between the segments bounded by the 1st g. p. nerve and the posterior spine and those which give off the post-girdle fin nerves. These correlations (Tables 7 *a* and *b*) have been worked out for the ♂ and ♀ adults and the values obtained are ·343 and ·370 respectively. On the hypothesis under consideration we should expect these correlations to approximate to unity and the lowness of the values actually obtained tells strongly against the

TABLE 7.

Correlation of Segments lying between First Girdle-piercing Nerve and Posterior Spine with Segments giving off Post-girdle Nerves to Fin.

a. ♂s.

	10	*11*	*12*	*13*	*14*	
8	—	2	3	—	—	5
9	2	8	25	8	1	44
10	1	1	16	10	—	28
11	—	—	1	5	—	6
	3	11	45	23	1	83
$r = ·343 \pm ·063$						

b. ♀s.

	10	*11*	*12*	*13*	*14*	
6	—	1	2	—	—	3
7	—	8	14	1	—	23
8	1	11	31	17	3	63
9	—	2	3	8	4	17
10	—	—	1	—	1	2
	1	22	51	26	8	108
$r = ·370 \pm ·056$						

hypothesis of intercalation. Lastly there is to be considered the possibility that the variations in the number of the meristic series and of its various portions are due to random addition to or subtraction of segments from a normal number. This is a point which, though of the greatest interest to students of variation, is yet extremely difficult for the biologist to test. In the following paragraphs Prof. Pearson has very kindly undertaken this task. It is sufficient here to emphasize his conclusion that the observed correlations are not in agreement with the correlations calculated upon the hypothesis under consideration. In other words random interpolation or excision of segments will not explain the variations observed, and we are consequently forced to adopt the principle of homoeosis as the only conception hitherto offered which affords an explanation of all the facts.

[*On the Random Increase and Decrease of Segments and on the Correlations between the three Vertebral Regions of Spinax niger.*

BY KARL PEARSON.

I must first state that I do not fully grasp either the hypothesis of excalation or homoeosis, or the manner in which biometric analysis can be used as a criterion between them. But we can, I think, ask how far the *existing* correlations are in keeping with:

(i) the proportional insertion of segments into a series of three mean groups;

(ii) the random insertion of segments into the same groups.

Let x = number of segments up to anterior spine, which we will call the anterior series.

y = number between anterior and posterior spines, which we will call the median series.

z = number beyond posterior spine, which we will call the posterior series.

t = total segments $= x + y + z$.

Let us suppose all these quantities measured in whole vertebrae as units.

Let the mean numbers be $\bar{x}, \bar{y}, \bar{z}, \bar{t}$. Suppose variations ξ, η, ζ, τ to occur in these numbers, so that

$$\tau = \xi + \eta + \zeta.$$

Then if τ were always distributed in any definite proportions whatever between the three groups, say:

$$\xi = p_1\tau, \quad \eta = p_2\tau, \quad \zeta = p_3\tau,$$

where $p_1 + p_2 + p_3 = 1$, we should have

$$\sigma_x = p_1\sigma_\tau, \quad \sigma_y = p_2\sigma_\tau, \quad \sigma_z = p_3\sigma_\tau,$$

or:

$$\sigma_\tau = \sigma_x + \sigma_y + \sigma_z,$$

$$r_{yz} = r_{zx} = r_{xy} = r_{xt} = r_{yt} = r_{zt} = 1.$$

These are manifestly inconsistent with the observed values. For adult ♂s I find:

$$\begin{array}{llll}
\bar{x} = 15{\cdot}979, & \sigma_x = {\cdot}670, & \text{C. of V. for} & x = 4{\cdot}194, \\
\bar{y} = 24{\cdot}561, & \sigma_y = {\cdot}785, & \quad " \qquad " & y = 3{\cdot}198, \\
\bar{z} = 24{\cdot}500, & \sigma_z = {\cdot}794, & \quad " \qquad " & z = 3{\cdot}240, \\
\bar{t} = 65{\cdot}040, & \sigma_t = 1{\cdot}048, & \quad " \qquad " & t = 1{\cdot}611,
\end{array}$$

which are far from satisfying the above relations.

Clearly: (i) judged either by the standard deviations or by the coefficients of variation the median and posterior series are equally variable, (ii) the anterior series is absolutely less variable than the median or posterior series, but relatively more variable, and (iii) absolutely the whole series is more variable than any subseries only in the ratio 4 to 3, and relatively it is far less variable.

The existing correlation and variation values are not given by any distribution of insertions and withdrawals in which the ratio of the changes in the subgroups to the total change remains constant.

Next suppose the segments inserted at random, there being no relation whatever between the numbers inserted in any of the subseries. We should then have

$$r_{xy} = r_{xz} = r_{yz} = 0,$$

$$r_{xt} = \sigma_x/\sigma_t, \quad r_{yt} = \sigma_y/\sigma_t, \quad r_{zt} = \sigma_z/\sigma_t,$$

$$r_{x+y,\,t} = \sigma_{x+y}/\sigma_t, \qquad r_{x,\,x+y} = \sigma_x/\sigma_{x+y}.$$

But $\sigma_{x+y} = {\cdot}888$. Hence we should expect, with the observed values of the variabilities:

$$r_{xt} = {\cdot}6393, \quad r_{yt} = {\cdot}7494, \quad r_{zt} = {\cdot}7573, \quad r_{x+y,t} = {\cdot}847, \quad \text{and} \quad r_{x,\,x+y} = {\cdot}7550.$$

Actually we have:

$$\begin{array}{lll}
r_{yz} = +{\cdot}0671, & r_{xt} = {\cdot}1544, & r_{x+y,\,t} = +{\cdot}6753, \\
r_{zx} = -{\cdot}3797, & r_{yt} = {\cdot}6318, & r_{x,\,x+y} = +{\cdot}5216, \\
r_{xy} = -{\cdot}2633, & r_{zt} = {\cdot}5648, &
\end{array}$$

which differ very sensibly from the above values.

Clearly additional segments are inserted in the three subseries in a correlated manner, and the existing series could not result from a mere random insertion of segments, or a proportioned insertion (nor of course by like withdrawals). Whether the original variation was of one of these kinds and the result was then modified by selection, it does not seem possible to assert on the basis of a statistical examination of *one* race at *one* epoch.

We can of course analyse the existing relationships; we have the following tables:

Regression Coefficients.

Gives in	Change of a unit in			
	x	y	z	t
x	1	− ·225	− ·321	·099
y	− ·309	1	·066	·473
z	− ·450	·068	1	·428

The following are the percentage changes in x, y, z:

Gives percentage change in	Change of a unit in			
	x	y	z	t
x	—	− 1·41	− 2·01	·62
y	− 1·26	—	+ ·27	1·93
z	− 1·84	+ ·28	—	1·75

These results appear of considerable interest. We see (i) that a gain of one in the total segments makes on the average five times as much absolute effect, and three times as much percentage effect on the median and posterior as on the anterior series: (ii) that a gain in either median or posterior series is accompanied by a very small gain in either posterior or median series respectively, but in both cases by a sensible loss in the anterior series. (iii) Conversely a gain in the anterior series is associated with sensible losses in median and posterior series; and (iv) gains and losses in anterior and posterior series have the highest relation, i.e. the loss of a segment in the anterior series is accompanied by a considerably greater gain in the posterior series than in the median series, and the gain of a segment by a greater loss in the posterior than in the median series. This more intimate relation of the extreme series than of either with the median series seems of considerable suggestiveness.

Lastly I have worked out the partial correlation coefficients of the three subgroups on the hypothesis that the total number of segments remains constant, i.e. expressions like:

$$R_{xy} = (r_{xy} - r_{xt} r_{yt}) / \sqrt{(1 - r_{xt}^2)(1 - r_{yt}^2)}.$$

I find

$$R_{xy} = -\cdot 4712, \quad R_{xz} = -\cdot 5727, \quad R_{yz} = -\cdot 4530.$$

Or we find a sensible negative correlation nearly equal to − ·5 between all three series. That is to say that if individuals of the same number of total segments be taken, we do not find all the subgroups either constant or again independent, but since the variabilities of the three are not widely different, the loss of a segment by one is roughly on the average an equally divided gain to the other two. For example if the anterior series lose a segment, this is not added wholly to the median series, but rather more than the half goes on the average to the posterior series. In other words *for fish of the same total number of segments* a forward movement of the anterior spine will on the average be associated with a forward movement of the posterior spine through somewhat more than half the number of segments through which the anterior spine moves.

It would thus appear that the existing system of variations and correlations is not consistent with any definite position of the two spines for fish of a constant number of segments; it is not consistent with any system of independent shifting of the spines about their mean positions in the same fish. It is only consistent with an associated motion of the two spines in the same direction, their average motions having a simple ratio. Thus, while the division between whole and half vertebrae (see ftn. p. 331) appears to vary in a manner not inconsistent with random interpolation into the total series, the relation between the three groups determined by the two spines appears to be of a wholly different character.]

III. HEREDITY OF MERISTIC CHARACTERS.

Shortly after the collection of the present data was begun the idea suggested itself that, owing to the viviparous nature of *Spinax*, such data might be used for the determination of fraternal and parental correlations. For purposes of fraternal correlation, 230 embryos belonging to 27 families (110 ♂s and 120 ♀s, cf. Appendix, Table 13, Nos. 75—304) are available. As the ♀ parent was not determined in Nos. 163—168 the number of embryos of which use can be made for calculating parental correlations is 224, belonging to 25 families. The actual calculation of the correlation coefficients, involving correction for the selection of both parents, was very kindly undertaken by Dr A. Lee in Prof. Karl Pearson's Laboratory, and the results are given in Table 8. The ♂ parents are of course unknown, but their influence has been deduced from the data given for ♂ adults on the assumption that the selection of ♂ parents from the adult ♂ population is equal to that of ♀ parents from adult ♀s.

Fraternal Correlations.

A glance at Table 8 at once brings out two points of interest, viz. (i) the diversity of the correlation values for the five characters treated, and (ii) the lowness of the average value even after parental selection has been corrected for.

(*a*) The diversity of the correlation values is very considerable, being as high as ·447 for the whole vertebrae, and as low as ·254 for the half vertebrae. Moreover when the sexes are considered separately these differences still obtain (cf. Appendix, Tables 38 to 42). Thus, in the case of total segments, the uncorrected value for ♂s is ·395, for ♀s ·410, and for siblings ·429, values which are all very close together. In one case however, that of the whole vertebrae, the value for the ♂s, i.e. ·541, is considerably higher than that for the ♀s, i.e. ·371. An examination of Table 40 shows that this is largely due to the exceptionally close correlation between the six ♂ offspring of ♀ 159 (Table 13, Nos. 261, 263—5, 267, 268), in all of which the number of whole vertebrae is unusually low. In the ♀s of the same family the number of whole vertebrae approximates more closely to the normal. There can be no doubt but that this small group of ♂s is largely responsible for the relatively high value of the fraternal correlation for whole vertebrae.

TABLE 8*.

Fraternal Correlations.

	Raw value	Corrected (a)	Corrected (b)
Anterior spine ...	·309 ± ·014	·320	·331
Posterior spine ...	·373 ± ·013	·394	·414
Whole vertebrae ...	·425 ± ·012	·436	·447
Half vertebrae ...	·228 ± ·014	·241	·254
Total segments ...	·429 ± ·012	·425	·422
Mean	·353	·363	·374

(a) Corrected for selection of mothers out of adult ♀ population.

(b) Corrected for selection of fathers also, on the assumption that they although unknown were equally selected with mothers.

(*b*) The average value of the five correlated characters works out after correction to ·375. This value is very much lower than the ·5 that the Law of Ancestral Heredity would have led us to expect†, and is markedly lower than the ·475 for eye-colour in man—the lowest value hitherto recorded (cf. Pearson, **'03**, p. 390). In this connection, however, there is a contingency which must not be overlooked, viz. the possibility that a ripe ♀ may be fertilized by more than one ♂. If this be so it would obviously lower the value of the fraternal correlation. We are entirely ignorant of the breeding habits of *Spinax*, but the following circumstantial evidence, slender though it is, seems to tell against the above conjecture. In the virgin ♀ the openings of the oviducts are occluded by the so-called hymen which must be ruptured before fertilization can be achieved.

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* Sheppard's correction has been made use of in the three following Tables 8—10.

† [The Law of Ancestral Heredity in no way fixes the value of the fraternal correlation, but only the ratios of *parental* correlation to that of higher ancestors. A fraternal value ·5 to ·6 is found *by observation* on *long* series in man, horse, dog, etc. Galton's data gave ·375 for stature in brother and sister. K.P.]

This is doubtless effected by the claspers of the ♂, powerful intromittent organs deeply grooved for the conveyance of the seminal fluid, and armed with strong spines. Their structure, taken in conjunction with the absence of an ejaculatory apparatus, points to copulation being no momentary action. Now, in several specimens of *Spinax*, I was able to examine the embryos in a very early condition shortly after the appearance of the medullary folds. Such early embryos were all at approximately the same stage, a fact which, considered in relation with what precedes, points to fertilization by a single ♂ only. Further reference to the low values of the fraternal correlations will be made later.

Absence of Differential Sex Variability in Mothers.

Whether ♀s of a given type tend to produce an excess of either sex is a question which the present data allow of an attempt at answering. The ♀ parents were weighted for each character with reference to ♂ and ♀ offspring separately, and the means and standard deviations of these two sets of weighted mothers were calculated. The results are given in Table 9.

TABLE 9.

Showing Variability of Mothers weighted for ♂ and ♀ Offspring respectively.

{Number of ♂ Offspring = 109; number of ♀ Offspring = 115.}

		M.	P. E. M.	σ	P. E. σ
Anterior spine	♂	16·284	± ·045	± ·7051	± ·032
	♀	16·322	± ·042	± ·666	± ·030
Posterior spine	♂	41·082	± ·046	± ·718	± ·033
	♀	41·035	± ·043	± ·672	± ·031
Whole vertebrae	♂	45·248	± ·056	± ·867	± ·040
	♀	45·156	± ·051	± ·819	± ·036
Half vertebrae	♂	39·853	± ·105	± 1·619	± ·074
	♀	39·852	± ·109	± 1·739	± ·077
Total segments	♂	65·440	± ·068	± 1·062	± ·048
	♀	65·365	± ·066	± 1·050	± ·046

The values both of the means and of the standard deviations are exceedingly close in every case. Only for the standard deviation of total segments is the difference between the ♀ parents, weighted for ♂ and ♀ offspring respectively, greater than twice the P. E. σ. The average value of σ for the five characters in the case of the ♂s is ·994 and for the ♀s ·989. From this it may be fairly concluded that the production of an excess either of ♂ or of ♀ offspring is not associated with any difference of type in the ♀ parent.

Parental Correlations.

The parental correlations, like the fraternal, exhibit great diversity in value for the five characters chosen, varying after correction from ·215 for the half vertebrae up to ·411 for total segments. This last value, which is the highest of the series, is low in comparison with the value of parental heredity in other forms in which Pearson and Lee find that "its values lie between ·42 and ·52 and cluster round ·48" (**'03**, p. 379). The lowness of the average value for the five characters is yet more marked, being when corrected only ·307 (cf. Table 10), an exceedingly low value for parental heredity. Allusion has already been made (p. 333) to the possibility of some changes in the meristic series occurring during growth from the natal to the adult condition. Even if we suppose that such changes occur it is probable that they are fairly uniform, and as all the embryos examined were at approximately the same stage it is unlikely that the low values of the parental correlations are in any measure due to growth factors.

TABLE 10.

Parental Correlations.

	Raw value	Corrected value (a)
Anterior spine ...	·359 ± ·039	·378
Posterior spine ...	·196 ± ·043	·264
Whole vertebrae ...	·168 ± ·044	·215
Half vertebrae ...	·238 ± ·042	·270
Total segments ...	·416 ± ·037	·411
Mean	·275	·307

(a) The values given in the second column are corrected for selection of mothers out of adult ♀ population.

The low values of both the fraternal and parental correlations in *Spinax* are of great interest in connection with a recent contribution of Pearson, "On a Generalized Theory of Alternative Inheritance" (**'04**). Basing his calculations on the conception of gametic purity Pearson finds that the value of the parental correlation should be about ·3, that of the fraternal between ·3 and ·4. These theoretical values are considerably below the values hitherto deduced from actual observations (**'03**, pp. 379 and 387), and for this reason Pearson is inclined to pronounce against a theory of inheritance involving the conception of gametic purity. "The present investigation," he writes, "shows that in the theory of the pure gamete there is nothing in essential opposition to the broad features of linear regression, skew distribution, the geometric law of ancestral correlation, etc., of the biometric description of inheritance in populations. But it does show that the generalized theory here dealt with is not elastic enough to account for the numerical values of the constants of heredity hitherto observed" (**'04**, p. 86). These theoretical values do however agree closely with the average values found for *Spinax*, and it must not be forgotten that we are here dealing with obviously discontinuous characters capable of simple numerical appreciation, and differing in nature, as far as we can at present judge, from any yet investigated. It may well be that the heredity of such characters is governed by Mendelian principles, though at present these principles are impossible of demonstration, owing to the existence of more than one pair of simple, or perhaps also of compound allelomorphs. To account for such families as that comprising embryos Nos. 260—270 is difficult except on an hypothesis of dominance, or on Pearson's hypothesis of "unit prepotency" (**'03**, p. 389). Here a family of 11 embryos of both sexes exhibits without exception extreme backward homoeosis, whilst the ♀ parent is characterized by marked forward homoeosis. It seems most natural to account for such a case by supposing that the unknown ♂ parent showed extreme backward homoeosis, and that this condition was dominant over that of marked forward homoeosis. The data are however too scanty and the possibilities too numerous to admit of profitable discussion on these points at present. More is doubtless to be learnt by selecting some simpler case in which the breeding can be easily controlled. This much new knowledge has at any rate been gained by the application of biometric methods, for the magnitude of the parental and fraternal correlations cannot but mean that the varying number of units in a primary linear meristic series does not depend alone on the individual environment, but that it is a character transmissible from one generation to another.

IV. SUMMARY.

The chief results obtained from an examination of certain meristic characters in 567 specimens of *Spinax niger* may be briefly summarized as follows :—

(1) A well-marked sexual dimorphism permeates the meristic series, the ♂s showing a greater tendency to backward homoeosis than the ♀s.

(2) Equal numbers of ♂s and ♀s are born but the evidence derived from the numbers caught points to a preponderance of ♀s in the adult state.

(3) The variability of the ♂ embryos (as measured by the standard deviation) is markedly higher than that of the ♂ adults. In the case of the ♀s the variability is not very different in embryos and adults. This points to more stringent selection among the ♂s and accords well with the circumstance of their relative scarcity when adult.

(4) A comparison of the variability in different parts of the meristic series tells strongly against the hypotheses of vertebral intercalation or excalation; and this holds good either on the view that such processes occur uniformly, or that they

are brought about by random excision or interpolation of segments. The various positions of the different characters studied (e.g. spines &c.) are probably due to homoeosis, and the reality of this factor is brought out by a study of the correlations with one another of the various characters chosen.

(5) The study of the variations of the girdle canals supports the view that the different positions of the pelvic girdle are brought about by a process of homoeosis as opposed to one of excalation or intercalation.

(6) Certain discrepancies in the correlation values are most readily explicable on the supposition that some homoeotic changes take place between birth and the adult state. Probably only a few characters are affected, and notably the anterior spine.

(7) Although the ♂s exhibit backward homoeosis as compared with the ♀s there is no tendency for ♀ parents exhibiting marked backward homoeosis to produce more ♂ offspring, or for ♀s showing forward homoeosis to give rise to families having a larger proportion of ♀s.

(8) The values of the fraternal and parental correlations are much below what would be expected on the Law of Ancestral Heredity* and accord better with the theory of gametic purity for the characters studied. Nevertheless the values of these correlations are sufficiently large to prove that the number of units in a primary linear meristic series is not solely due to the individual environment but is a character transmitted from generation to generation.

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* [See footnote, p. 342. K. P.]

EXPLANATION OF PLATE.

Fig. 1, *a*—*c*. Showing the different positions of the anterior spine with regard to the vertebral cartilages. The numbers refer to the whole vertebra to which the spine is regarded as belonging. *bd* = basidorsal cartilage, *id* = interdorsal cartilage. 1*a* is taken from No. 146, 1*b* from 147 and 1*c* from 148 of the ♀ adults.

Fig. 2. Caudal end of embryo No. 139 × 8. The no. 30 indicates the 30th half vertebra.

Fig. 3. Caudal end of embryo No. 85 × 8. The 33rd and 34th half vertebrae are not separated as regards their centra.

Fig. 4. Longitudinal section through occipital region of skull and first few vertebrae. From ♀ adult No. 53. The spinal cord and brain have been removed.

Fig. 5. Preparation similar to Fig. 4. From ♀ adult No. 45. There is less condensation at the base of the skull than in the preceding figure.

Fig. 6, *a*—*c*. Longitudinal sections through the junction of half and whole vertebrae. The last whole vertebra is in each case numbered. 1*a* is taken from ♀ adult No. 64, 1*b* from ♀ adult No. 26, and 1*c* from ♀ adult No. 34.

Fig. 7. View of vertebral column of a single specimen after cleaning. In this specimen there are 42 whole vertebrae and 43 half vertebrae. The anterior spine is carried by vertebra 16, the posterior by vertebra 40. The dorsal spines in the caudal region have been omitted.

Note to Appendix, Tables 11—12.

These two tables present the raw data for adults of both sexes. Of the abbreviations used g. p. n. signifies the 1st girdle-piercing nerve, p. g. n. the post-girdle nerves, and coll. n. the number of nerves which take part in the formation of the *nervus collector*. Length w. v. and length h. v. denote the length of the series of whole and half vertebrae respectively and the values given are expressed in centimetres. When two numbers are given for the g. p. n. in a bracket as in individuals 9—11 of Table 11 it signifies that there are 2 g. p. n. and that both right and left sides are similar.

APPENDIX.

TABLE 11. ♂ *adults.*

Individual		*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
G. p. n. r.	29	30	28	29	28	29	29	28	29	28	27	28	29	28	29	26	28	29	29	27	28	28
l.	,,	29-30	29	,,	,,	,,	,,	,,	30	29	28	28-29	,,	29	,,	27	,,	,,	,,	28	,,	29
P. g. n. r.	9	7	9	9	10	9	9	9	9	10	11	10	9	10	9	11	10	10	9	11	9	10
l.	,,	8	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,
Coll. n. r.	6	6	5	6	5	5	5	5	5	5	4	5	5	5	6	5	5	6	5	5	6	5
l.	,,	,,	,,	,,	,,	,,	6	,,	,,	,,	5	,,	,,	,,	,,	,,	6	,,	,,	,,	,,	,,
Ant. sp.	—	—	16	16	16-17	17	16	16	16	16	16	16	18	16	16	16	16	16	16	16	15	15
Post. sp.	39	39	40	40	40-41	42	41	40	41	40	40	40	41	41	41	39	40-41	41	41	40	41	40
W. vert.	45	45	44	45	45	44	45	44	45	44	42	44	45	45	45	43	44	45	45	44	46	45
H. vert.	37	39	42	38	38	44	36	40	40	43	43	41	40	38	40	40	42	40	38	37	37	40
Total segs.	64	65	65	64	64	66	63	64	65	66	64	65	65	64	65	63	65	65	64	63	65	65

Individual	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*	*39*	*40*	*41*	*42*	*43*
G. p. n. r.	28	28	27-28	29	29	29	29	30-31	28	28-29	27	30	28	29	28	29	28	28	28	30	28
l.	29	29	28-29	30	30	30	28-29	30	29	29	28	31	,,	28-29	,,	,,	,,	29	,,	,,	,,
P. g. n. r.	9	10	11	9	9	9	9	9	10	10	10	9	9	9	9	8	10	11	9	9	9
l.	,,	,,	10	,,	,,	,,	10	,,	,,	9	,,	,,	,,	10	,,	,,	,,	,,	,,	,,	,,
Coll. n. r.	5	5	5	5	6	6	6	6	5	5	5	6	6	6	5	6	5	5	4	5	5
l.	,,	,,	6	,,	,,	,,	5	,,	6	,,	,,	,,	,,	5	,,	,,	,,	,,	,,	,,	,,
Ant. sp.	15	15	15-16	16	17	16-17	16	16	15	16	16	18	16	16	15	16	16	17	15	16	15
Post. sp.	39	39	41	42	41	42	40	42	40	40	40	42	40	41	40	41	40	40	39	41	39
W. vert.	43	43	45	47	45	46	43	46	45	45	44	47	44	45	43	46	44	45	44	45	44
H. vert.	40	41	39	40	38	38	43	42	41	40	40	38	38	40	42	39	42	41	41	42	39
Total segs.	63	64	65	67	64	65	65	67	66	65	64	66	63	65	64	66	65	66	65	66	64

Individual	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*	*52*	*53*	*54*	*55*	*56*	*57*	*58*	*59*	*60*	*61*	*62*	*63*
G. p. n. r.	29	27	30	28	29	28	29	30	29	28-29	28	29	29	28	29	29	27	29-30	30-31	29
l.	,,	,,	31	,,	30	29	,,	,,	28-29	29	29	,,	,,	29	30	,,	28	29	31	,,
P. g. n. r.	9	10	8	10	10	9	8	9	9	8	9	9	9	9	9	8	10	9	9	9
l.	,,	,,	,,	,,	,,	,,	,,	,,	10	,,	,,	,,	,,	,,	,,	,,	,,	,,	8	,,
Coll. n. r.	5	5	5	5	4	5	6	6	5	5	5	5	5	5	6	6	4	4	5	6
l.	,,	4	,,	,,	,,	,,	,,	5	4	,,	,,	,,	6	,,	,,	,,	,,	,,	6	,,
Ant. sp.	16	16	16	16	17	15	16	15-16	16-17	16	16	16	16	16	16	16	15	16	17	15
Post. sp.	41	39-40	41	40	41	40	40	41	40-41	40	41	41-42	41	42	41	41	40	41	42-43	40
W. vert.	45	43	45	44	45	44	44	46	46	43	44	46	45	46	46	45	44	45	48	45
H. vert.	40	43	42	41	38	41	40	38	37	43	44	42	40	41	41	41	39	42	37	41
Total segs.	65	65	66	65	64	65	64	65	65	65	66	67	65	67	67	66	64	66	67	66
Length w. v.	—	—	18·6	18·3	19·7	19·8	19·9	16·2	19·6	21·2	19·5	19·9	16·2	20·5	18·8	16·5	17·4	16·7	19·1	15·2
Length h. v.	—	—	10·1	10·4	10·1	11·0	10·2	9·2	9·1	12·1	11·7	10·5	9·2	11·0	10·0	8·8	9·6	9·9	9·5	8·3
Total length	—	—	28·7	28·7	29·8	30·8	30·1	25·4	28·7	23·3	31·2	30·4	25·4	31·5	28·8	25·3	27·0	26·6	28·6	23·5

Individual	*64*	*65*	*66*	*67*	*68*	*69*	*70*	*71*	*72*	*73*	*74*	*75*	*76*	*77*	*78*	*79*	*80*	*81*	*82*
G. p. n. r.	29	29	30	31	28	29	28	28	29	28	27	28-29	28	29	29	28	28	29	29-30
l.	29-30	28-29	31	,,	29	,,	,,	,,	,,	29	28	28	,,	,,	,,	29	,,	,,	29
P. g. n. r.	9	9	9	8	9	9	10	9	10	9	10	9	9	10	10	10	9	9	9
l.	8	10	8	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	9	,,	,,	,,	,,	,,
Coll. n. r.	6	6	6	6	5	5	5	5	6	5	4	5	6	5	5	5	5	6	5
l.	,,	5	7	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	6	,,	,,	,,	,,	6
Ant. sp.	15	15-16	16	17	15	17	16	16	16	16	15	15-16	15	15	16	16-17	16	15	16
Post. sp.	40	41	43	43	40	41	40	41	39	40	40	40	40	41	41	40-41	40	39	40-41
W. vert.	44	45	47	48	45	44	43	43	44	45	44	43	44	46	46	45	43	43	44
H. vert.	41	40	40	39	40	41	45	44	39	40	41	43	39	39	40	40	42	41	41
Total segs.	65	65	67	68	65	65	66	65	64	65	65	65	64	66	66	65	64	64	65
Length w. v.	17·0	20·2	20·2	19·7	20·9	20·0	19·2	14·0	15·1	20·4	19·5	19·0	19·5	20·2	18·3	18·2	17·4	16·2	19·3
Length h. v.	8·9	10·3	10·3	9·6	9·1	10·8	11·3	9·1	8·5	10·3	10·4	10·9	10·3	10·4	10·1	9·8	10·6	9·3	10·2
Total length	25·9	30·5	30·5	30·3	30·0	30·8	30·5	23·1	23·6	30·7	29·9	29·9	29·8	30·6	28·4	28·0	28·0	25·5	29·5

Individual	*83*	*84*	*85*	*86*	*87*	*88*	*89*	*90*	*91*	*92*	*93*	*94*	*95*	*96*	*97*	*98*	*99*	*100*
G. p. n. r.	28	29	29-30	29-30	28	28	27	28-29	28	29	27	28	28	28-29	29	29	28	27
l.	29	,,	,,	,,	29	29	28	28	,,	,,	,,	29	,,	29	,,	30	,,	,,
P. g. n. r.	10	10	9	9	10	9	10	10	9	9	11	10	10	10	9	8	10	11
l.	,,	,,	10	10	,,	,,	,,	,,	,,	,,	,,	,,	,,	9	,,	,,	,,	,,
Coll. n. r.	5	6	6	6	5	5	4	5	5	6	4	4	5	5	5	6	5	4
l.	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	6	,,	5	,,	,,
Ant. sp.	15	17	16	16	17	15	15	15-16	16	17	15	16	16-17	16	16	16	16	16
Post. sp.	40	41	41	41-42	40	40	39	41	40	41-42	40	41	39-40	41	40	40	40	40
W. vert.	44	44	46	46	44	44	43	44	45	46	43	44	44	44	45	43	44	46
H. vert.	41	42	40	42	40	39	40	43	38	39	43	42	40	45	39	43	41	37
Total segs.	65	65	66	67	64	64	63	66	64	66	65	65	64	67	65	65	65	65
Length w. v.	20·2	15·8	19·8	19·8	17·8	19·6	18·4	17·6	20·7	18·8	18·2	18·8	19·2	17·8	16·7	18·9	20·0	19·7
Length h. v.	10·7	9·5	10·1	10·8	9·3	10·6	10·4	10·4	10·2	10·2	9·9	11·4	10·3	10·9	9·7	11·6	11·4	8·9
Total length	30·9	25·3	29·9	30·6	27·1	30·2	28·8	28·0	30·9	29·0	28·1	30·2	29·5	28·7	26·4	30·5	31·4	28·6

TABLE 12.

♀ *adults.*

Individual		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
G. p. n.	r.	30	29	29	30	28	28	28-29	28	30	30	29	29	29-30	29-30	30-31	30	30	29	29	30	29	31
	l.	31	,,	,,	31	29	29	29	29	,,	,,	,,	,,	29	28-29	30	,,	,,	30	30	31	30	,,
P. g. n.	r.	8	7	7	8	9	9	8	9	6	8	7	8	7	7	8	8	8	9	8	8	8	6
	l.	,,	,,	,,	,,	,,	,,	7	,,	,,	,,	,,	,,	,,	8	,,	,,	,,	8	,,	,,	7	,,
Coll. n.	r.	6	6	6	6	4	4	5	5	6	5	6	5	6	6	5	6	6	6	5	6	6	6
	l.	,,	,,	5	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	5	,,	,,	,,	7	,,	,,	,,	,,
Ant. sp.		—	—	—	—	—	—	—	—	—	16	16	16-17	17-18	16-17	17	17	17	16	17	17-18	16	16-17
Post. sp.		—	—	—	—	42	41-42	41	42	42	42	41	41-42	41-42	41	42-43	41	43	41-42	42	42-43	41	42-43
W. vert.		47	44	45	46	45	46	45	45	44	46	45	46	45	44	46	45	47	45	45	47	45	47
H. vert.		39	41	38	41	46	39	39	41	43	38	40	39	41	42	42	40	42	43	41	38	39	39
Total segs.		67	65	64	67	68	66	65	66	66	65	65	66	66	65	67	65	68	67	66	66	65	67

Individual		*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*	*39*	*40*	*41*
G. p. n.	r.	29	30	30	29	30	30	28	29	28	29	29	29	28	29	29	28	28-29-30	29	29
	l.	,,	,,	,,	,,	29-30	,,	29	,,	29	,,	,,	,,	29	30	30	,,	,,	30	30
P. g. n.	r.	8	7	8	7	8	8	9	8	9	8	7	8	8	8	9	9	9	8	8
	l.	7	8	,,	,,	,,	,,	8	,,	,,	,,	8	,,	,,	,,	,,	,,	,,	,,	,,
Coll. n.	r.	6	6	5	6	5	5	6	6	5	5	5	6	5	5	5	5	4	5	5
	l.	,,	,,	,,	,,	4	,,	,,	,,	,,	6	,,	,,	4	,,	,,	,,	5	6	,,
Ant. sp.		16	16	17	17	16	17	16	16-17	16	17	16	16	16	15-16	16	16	16-17	16	16
Post. sp.		40-41	41	41-42	40-41	41	41	40	40	41	41	40	42	40	41	42	40	41	42	41
W. vert.		43	46	45	44	46	44	44	44	44	44	44	46	43	44	45	44	46	47	44
H. vert.		42	37	41	41	37	40	39	40	42	40	41	41	41	39	43	39	39	37	42
Total segs.		64	65	66	65	65	64	64	64	65	64	65	67	64	64	67	64	66	66	65

Individual		*42*	*43*	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*	*52*	*53*	*54*	*55*	*56*	*57*	*58*	*59*	*60*
G. p. n.	r.	30	29	30	29	28-29	30	29	28	29	29	29	30-31	29	30	30	28	30	31	29
	l.	29-30	30	31	30	29	,,	30	,,	30	,,	,,	30	,,	,,	29	29	,,	,,	,,
P. g. n.	r.	7	8	8	8	10	7	8	8	8	8	7	8	8	7	7	8	7	8	8
	l.	8	,,	,,	,,	9	,,	,,	,,	,,	,,	8	,,	,,	,,	8	,,	,,	7	,,
Coll. n.	r.	6	5	6	6	4	5	6	5	5	5	5	6	5	5	7	5	6	6	5
	l.	5	6	,,	,,	5	,,	,,	6	,,	,,	6	,,	,,	,,	6	,,	,,	,,	6
Ant. sp.		16	16-17	15-16	17	16	15-16	15	16	16	17	15	—	—	—	—	—	—	—	—
Post. sp.		41-42	42	41-42	42	41	40-41	41	40	42	41	41	43-44	41	42	42	42	42	44	39
W. vert.		47	45	45	48	45	46	44	44	46	45	45	48	44	45	45	46	47	48	44
H. vert.		38	41	42	37	42	37	42	39	36	40	37	39	42	40	40	37	38	40	39
Total segs.		66	66	66	67	66	65	65	64	64	65	64	68	65	65	65	65	66	68	64
Fin rays		—	—	—	—	—	—	—	—	—	—	—	18	17	18	18	17	18	20	16

Individual		*61*	*62*	*63*	*64*	*65*	*66*	*67*	*68*	*69*	*70*	*71*	*72*	*73*	*74*	*75*	*76*	*77*	*78*	*79*	*80*	*81*
G. p. n.	r.	29	27	30	28	30	29	29	29	29	28-29	29	29	29	28	29	29	29-30	30	29-30	28-29	28-29
	l.	,,	28	,,	,,	31	,,	30	,,	,,	29	30	,,	30	29	,,	,,	30	31	30	29	29
P. g. n.	r.	8	10	7	9	8	8	9	8	8	9	9	7	9	8	8	8	8	7	9	9	10
	l.	,,	,,	,,	,,	,,	,,	,,	,,	,,	8	,,	,,	,,	,,	,,	,,	7	,,	8	8	8
Coll. n.	r.	5	5	5	6	5	6	5	5	5	4	5	6	6	5	6	5	5	6	5	5	4
	l.	,,	,,	,,	,,	,,	,,	,,	,,	,,	5	6	,,	5	,,	,,	,,	6	,,	,,	,,	5
Ant. sp.		—	15	17-18	16-17	16	16	15-16	15	16	15	16	16	16	16	15-16	16	16	16	17	16	16
Post. sp.		41	41	42	41	42	41-42	40	40	41-42	39-40	42	41	41-42	40	40	40	42	42	42	41	41
W. vert.		45	45	46	46	47	44	45	43	45	44	44	45	46	44	45	44	45	46	46	45	44
H. vert.		40	39	42	40	38	42	42	43	40	40	41	41	36	38	39	40	43	41	38	40	42
Total segs.		65	65	67	66	66	65	66	65	65	64	65	66	64	63	65	64	67	67	65	65	65
Fin rays		17	18	16	17	18	16	18	17	17	18	19	15	15	16	19	17	19	15	18	17	18

TABLE 12—(*continued*).

Individual		*82*	*83*	*84*	*85*	*86*	*87*	*88*	*89*	*90*	*91*	*92*	*93*	*94*	*95*	*96*	*97*	*98*	*99*	*100*	*101*	*102*	*103*	*104*
G. p. n.	r.	30	28	30	29	30	29	29-30	28	30	29	29	28	29	28	29	29	28	29	29	30-31	29	29	28
	l.	,,	29	31	,,	,,	,,	30	29	,,	,,	,,	,,	,,	,,	30	,,	,,	,,	,,	30	,,	,,	,,
P. g. n.	r.	7	9	7	8	7	8	8	8	6	8	7	8	8	9	8	7	9	8	8	7	7	8	8
	l.	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	8	,,	9	,,	,,	,,	,,	,,	,,	8	,,	,,	,,
Coll. n.	r.	6	5	5	5	6	5	4	5	6	5	5	5	5	5	5	5	6	5	5	6	5	5	5
	l.	,,	,,	,,	,,	,,	,,	6	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	5	6	6	,,
Ant. sp.		16-17	15	16	16	16	16-17	15-16	16	16	15-16	15-16	15	17	15	16	16	14	17	16	17	16	15-16	17
Post. sp.		42	40	42	40-41	41	41-42	41	40	41	41	41	39	41	41	41	40-41	39	42	40	41	40	41	40
W. vert.		45	43	46	44	46	46	45	45	46	44	44	44	45	46	44	44	44	43	44	45	44	46	44
H. vert.		41	45	39	42	40	39	40	39	38	42	42	40	41	39	41	44	41	48	41	42	43	38	42
Total segs.		66	66	66	65	66	66	65	65	65	65	65	64	66	66	65	66	65	67	65	66	66	65	65
Fin rays		17	17	17	18	15	16	17	17	17	16	16	15	16	19	17	17	19	16	16	16	18	19	18

Individual		*105*	*106*	*107*	*108*	*109*	*110*	*111*	*112*	*113*	*114*	*115*	*116*	*117*	*118*	*119*	*120*	*121*	*122*	*123*	*124*	*125*
G. p. n.	r.	28	30	30	28	30	29	29	29	29	29	30	30	28	27	29	29	29	29	30	29-30	28
	l.	29	,,	31	,,	30-31	,,	30	,,	,,	,,	29-30	,,	,,	,,	30	,,	28-29	30	29-30	30	,,
P. g. n.	r.	10	7	7	8	7	8	8	7	8	7	9	8	9	8	8	8	7	8	7	8	8
	l.	,,	,,	,,	,,	,,	,,	7	,,	,,	8	,,	7	,,	,,	,,	,,	8	,,	8	7	,,
Coll. n.	r.	5	5	5	5	6	5	5	5	6	5	6	5	5	5	5	5	5	5	5	4	6
	l.	,,	6	,,	,,	,,	,,	,,	,,	,,	,,	5	,,	4	,,	,,	,,	4	,,	4	5	,,
Ant. sp.		15	16	16-17	15	14	16	16	16	16	16	17	17	17	16	16	16	16	16	16	17	15
Post. sp.		40	42	41-42	40	41	41	42	40	41	40	42	42	41	41	41	41	39	41	41	41	40-41
W. vert.		45	45	45	45	45	44	45	45	45	46	45	46	45	44	46	45	44	45	44	45	46
H. vert.		38	43	41	39	39	41	41	40	40	37	43	39	41	42	37	39	40	41	42	40	37
Total segs.		64	67	66	65	65	65	66	65	65	65	67	66	66	65	65	65	64	66	65	65	65
Fin rays		17	16	17	17	16	15	16	18	17	20	17	17	18	17	17	16	17	18	18	17	17
Length w. v.		21·0	19·3	18·2	19·7	23·0	22·9	20·5	20·0	21·7	20·2	24·6	21·2	16·0	21·1	22·2	22·0	20·2	22·3	22·5	23·5	19·9
Length h. v.		10·5	10·7	10·7	10·1	11·2	12·0	11·2	10·5	11·0	9·7	12·4	10·5	9·1	11·7	10·6	10·4	10·9	11·4	11·2	12·0	9·9
Total length		31·5	30·2	28·9	29·8	34·2	34·9	31·7	30·5	32·7	29·9	37·0	31·7	25·1	32·8	32·8	32·4	31·1	33·7	33·7	35·5	29·8

Individual		*126*	*127*	*128*	*129*	*130*	*131*	*132*	*133*	*134*	*135*	*136*	*137*	*138*	*139*	*140*	*141*	*142*	*143*	*144*	*145*	*146*	*147*	*148*
G. p. n.	r.	30	29	30	29-30	29	29-30	28	29	27-28	30	29	28	28	30	29	28	29	30	29-30	29	29	29	29
	l.	31	30	,,	30	30	30	29	30	27	,,	,,	,,	29	,,	,,	,,	,,	31	29	,,	,,	,,	,,
P. g. n.	r.	8	8	7	9	8	7	9	8	9	8	9	9	8	7	8	8	7	8	8	7	7	8	8
	l.	9	,,	,,	8	,,	6	7	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	9
Coll. n.	r.	6	5	6	5	5	5	4	5	5	6	5	5	5	5	5	6	5	5	5	6	6	5	5
	l.	5	,,	,,	6	,,	6	5	,,	,,	,,	,,	,,	,,	,,	,,	5	,,	,,	,,	,,	,,	,,	,,
Ant. sp.		16-17	17	17	16	16	16	16	16	15	15	16	15	15	16	15	15	16	16	16	16	16	16	17
Post. sp.		42	41	41	42	42	42	40	42	40	41	42	40	40	41	41	39	41	42	41	41	40	41	42
W. vert.		47	46	46	47	47	45	44	46	44	45	45	44	43	45	45	43	45	47	46	45	44	44	45
H. vert.		38	39	38	38	40	43	41	41	40	43	42	41	41	43	43	41	40	40	40	40	42	42	42
Total segs.		66	66	65	66	67	67	65	67	64	67	66	65	64	67	67	64	65	67	66	65	65	65	66
Fin rays		17	18	18	—	17	17	18	18	16	18	17	16	16	17	19	18	—	17	16	18	16	19	17
Length w. v.		19·7	22·6	24·8	21·2	22·9	20·6	20·1	19·1	19·7	22·8	21·0	19·9	19·9	18·1	17·4	22·4	20·7	17·3	19·8	19·4	23·8	22·1	22·4
Length h. v.		10·3	10·7	11·8	9·8	10·8	10·2	11·1	10·2	10·4	11·8	10·9	11·1	11·9	10·2	10·2	11·6	11·5	9·0	10·9	11·0	11·8	12·2	11·9
Total length		30·0	33·3	36·6	31·0	33·7	30·8	31·2	29·3	30·1	34·6	31·9	31·0	31·8	28·3	27·6	34·0	32·2	26·3	30·7	30·4	35·6	34·3	34·3

Individual	*149*	*150*	*151*	*152*	*153*	*154*	*155*	*156*	*157*	*158*	*159*	*160*	*161*	*162*	*163*
Ant. sp.	15	15	16	16	16-17	16	16-17	17	17	17	17	16	16	16-17	16
Post. sp.	40	40	41	41	40	41	42	41	41	41	42	42	41	41	41-42
W. vert.	44	44	45	45	44	45	46	46	45	45	46	47	45	44	46
H. vert.	38	41	37	39	42	41	41	37	39	41	40	41	38	43	42
Total segs.	63	65	64	65	65	66	67	65	65	66	66	68	64	66	67

TABLE 13.

Embryos, ♂ and ♀.

Individual	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Sex	♀	♂	♀	♀	♀	♀	♀	♀	♀	♀	♀	♂	♂	♂	♂	♀	♀	♂	♂	♀	♂	♂	♂	♀	♂	♀	♀	♂
Ant. sp.	16	16	16	16	15	16	16	16	16	16	17	15	15	16	18	17	16	15	16	15	16	15	16	17	16	16	16	15-16
Post. sp.	41	39	39	40	40	40	39	40	41	41	42	40-41	40-41	40	42	41	41	40	42	41	41	40	40	42	41	40	41	40
W. vert.	45	43	42	45	43	44	43	44	45	46	45	45	44	44	44	45	45	44	47	44	45	44	44	46	43	44	44	44
H. vert.	38	39	40	38	40	41	41	43	40	38	44	40	41	40	45	36	36	38	38	40	42	40	38	40	42	40	40	39
Total segs.	64	63	62	64	63	65	64	66	65	65	67	65	65	64	67	64	63	63	66	64	66	64	63	66	64	64	64	64

Individual	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Sex	♂	♂	♀	♂	♂	♂	♀	♂	♂	♀	♀	♀	♂	♀	♂	♂	♂	♀	♂	♂	♀	♀	♀	♀	♂	♂	♂	♀
Ant. sp.	16	16	17	15-16	16	17	16	17	16	16	17	16	16	16	16	17	15	15	16	16	16	16	16	17	15	16	16	16
Post. sp.	42	41-42	41	40	42	42	41	42	41	41-42	42-43	43	41	40	41-42	41	40	40	43	39	41	42	42	40	40	40-41	39	40
W. vert.	45	46	44	45	47	46	44	47	45	46	47	47	46	44	46	45	44	43	51	43	45	47	48	43	43	44	43	43
H. vert.	38	38	40	38	38	38	40	36	40	42	38	38	38	40	40	41	38	42	32	38	38	38	36	41	42	39	40	42
Total segs.	64	65	64	64	66	65	64	65	65	67	66	66	65	64	66	66	63	64	67	62	64	66	66	64	64	64	63	64

Individual	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
Sex	♀	♂	♂	♀	♀	♀	♀	♀	♂	♂	♀	♀	♂	♂	♀	♀	♀	♂	♂	♂	♂	♀	♀	♀	♀	♀	♂	♂
nt. sp.	16	15-16	15-16	16	16	16	16	16	15	16	16	16	16	16	17	16	16	15	15-16	16	16	15	15	16	16	16	16	16
t. sp.	41	39-40	40	41	41	41	40	41	41	40	41	41-42	40	40	41	38	41	40-41	39-40	40-41	40-41	40	40	40-41	41	40	41	41
. vert.	44	42	43	45	44	45	44	44	46	43	44	47	44	45	44	43	47	44	44	45	44	43	43	44	44	43	45	45
. vert.	41	42	40	38	41	39	42	40	37	40	39	35	39	39	38	40	37	40	38	39	39	42	40	40	41	41	37	37
otal segs.	65	63	63	64	65	65	65	64	65	63	64	65	64	65	63	63	66	64	63	65	64	64	63	64	65	64	64	64

idividual	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112
Sex	♂	♂	♂	♂	♂	♀	♀	♀	♂	♂	♂	♀	♂	♀	♂	♂	♂	♀	♂	♀	♂	♀	♂	♀	♀	♀	♀	♂
Ant. sp.	16	16	16	16	15	16	16	16	16	16-17	16-17	17	16	16	16-17	16-17	16	16	16	16	16	15-16	15-16	16	16	16	16	16
Post. sp.	41	40	40	40	40	41-42	42	40	41	40	41	41	40	42	42-43	41-42	41	39-40	40-41	41-42	40-41	40	40	40	41-42	40	41	40
V. vert.	45	44	45	45	45	45	46	44	45	45	45	46	43	46	46	45	45	44	44	45	44	43	43	44	44	44	44	44
I. vert.	41	38	39	37	39	40	41	40	41	41	39	38	41	38	42	41	40	41	41	42	40	43	42	40	44	41	42	40
Total segs.	66	63	65	64	65	65	67	64	66	66	65	65	64	65	67	66	65	65	65	66	64	65	64	64	66	65	65	64

ndividual	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
Sex	♂	♀	♀	♀	♀	♀	♀	♂	♂	♂	♂	♀	♀	♂	♂	♂	♂	♂	♀	♀	♂	♀	♀	♀	♀	♂	♂	♀
Ant. sp.	16	15-16	15-16	15-16	16	16	15	16	15	15-16	15	15	16	16	16	16	16	16	16	16	16	16	16	15	16	16	16	15
Post. sp.	39	40-41	41	41-42	42	41	40	41	41	40	39-40	40	41	40	41	41	40	41	41	40	40	40	40-41	40	40	39	40	40
/. vert.	43	45	46	46	46	45	44	46	46	44	44	44	45	44	46	45	44	45	45	44	44	43	44	43	44	43	43	44
. vert.	43	38	37	37	39	39	40	38	39	40	40	42	39	41	39	40	40	40	40	40	39	41	41	40	38	40	40	41
Total segs.	65	64	65	65	66	65	64	65	66	64	64	65	65	65	66	65	64	65	65	64	64	64	65	63	63	63	63	65

idividual	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168
ex	♀	♀	♀	♀	♀	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♀	♀	♀	♀	♂	♀	♀	♀	♀	♀
nt. sp.	16	16	16	16	15-16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	15	16	16	16	16	16
ost. sp.	41	41-42	41	42	41	40-41	40	41	41-42	40-41	40	41	40	40	41-42	40	40	41	41	41	40	40	40	40	40	40-41	40	40
. vert.	45	46	45	45	46	45	44	45	46	45	44	46	44	44	47	45	45	46	45	45	44	45	42	44	44	45	44	45
H. vert.	39	38	39	40	38	40	40	42	40	40	42	39	42	42	39	40	40	39	42	40	41	40	44	39	41	40	40	39
Total segs.	65	65	65	65	65	65	64	66	66	65	65	66	65	65	67	65	65	66	66	65	65	65	64	64	65	65	64	65

TABLE 13—(*continued*).

Individual	*169*	*170*	*171*	*172*	*173*	*174*	*175*	*176*	*177*	*178*	*179*	*180*	*181*	*182*	*183*	*184*	*185*	*186*	*187*	*188*	*189*	*190*	*191*	*192*	*193*	*19*
Sex	♀	♀	♀	♂	♂	♂	♂	♀	♀	♂	♂	♀	♂	♀	♀	♀	♀	♂	♀	♀	♂	♂	♀	♂	♀	♂
Ant. sp.	16	16	16	16	16	16	16	15	15	15	15	16	16	15	16	17	16	16	16	17	17	16	16	16	16	1
Post. sp.	40	41	42	41	40	41	40	40	41	40	41	42	39	40	40	41	41	39	40	41	41	40	40	41	40	4
W. vert.	43	46	45	45	44	46	43	44	46	44	44	45	44	45	44	46	44	43	46	45	45	44	46	45	45	4
H. vert.	44	38	40	39	41	37	42	41	39	41	43	40	40	39	39	40	43	43	38	41	40	40	37	40	38	4
Total segs.	65	65	65	65	65	65	64	65	66	65	66	65	64	65	64	66	66	65	65	66	65	64	65	65	64	65

Individual	*195*	*196*	*197*	*198*	*199*	*200*	*201*	*202*	*203*	*204*	*205*	*206*	*207*	*208*	*209*	*210*	*211*	*212*	*213*	*214*	*215*	*216*	*217*	*218*	*219*	*22*
Sex	♂	♂	♀	♀	♂	♂	♂	♂	♂	♀	♀	♀	♂	♀	♂	♀	♀	♀	♂	♀	♂	♂	♀	♂	♀	♀
Ant. sp.	16	16	16	17	16	17	16	15-16	15	15	15	16	16	16	15	15	17	16	16	16	16	16	16	16	17	17
Post. sp.	40	40	41	41	40	42	41	40-41	40	40-41	41	40	40	40	40	39	42	42	41	41	42	41	41	40	42	42
W. vert.	45	45	46	45	45	47	46	45	44	45	45	45	45	45	44	43	46	45	45	46	46	46	44	43	46	47
H. vert.	40	39	38	42	41	36	39	39	41	39	39	38	39	41	38	40	40	43	43	41	42	39	42	43	41	40
Total segs.	65	65	65	66	66	65	66	65	65	65	65	64	65	66	63	63	66	67	67	67	67	66	65	65	67	67

Individual	*221*	*222*	*223*	*224*	*225*	*226*	*227*	*228*	*229*	*230*	*231*	*232*	*233*	*234*	*235*	*236*	*237*	*238*	*239*	*240*	*241*	*242*	*243*	*244*	*245*	*24*
Sex	♂	♀	♂	♂	♀	♂	♀	♀	♂	♂	♀	♀	♀	♀	♂	♂	♂	♀	♂	♀	♂	♀	♂	♀	♀	♀
Ant. sp.	17	17	16	16	17	16	17	17	16	18	15-16	17	16-17	17	16	17	15	16	15	17	16	17	17	17	16	17
Post. sp.	41	42	40	40-41	40	40	41	41	40	42	39	41	41	40	39	39	39	39	39	40	40	40	40	40	40	4
W. vert.	45	46	44	44	43	43	46	46	45	46	45	45	45	44	44	44	43	44	44	44	44	44	43	44	44	
H. vert.	42	41	38	40	40	43	39	39	36	38	39	37	38	39	40	42	41	40	38	39	43	41	40	42	41	
Total segs.	66	67	63	64	63	65	66	66	63	65	65	64	64	64	64	65	64	64	63	64	66	65	63	65	65	

Individual	*247*	*248*	*249*	*250*	*251*	*252*	*253*	*254*	*255*	*256*	*257*	*258*	*259*	*260*	*261*	*262*	*263*	*264*	*265*	*266*	*267*	*268*	*269*	*270*	*271*	*2*
Sex	♀	♀	♂	♀	♀	♂	♀	♀	♀	♀	♂	♀	♂	♀	♂	♀	♂	♂	♂	♀	♂	♂	♀	♀	♂	
Ant. sp.	17	17	17	15	16	15	15	17	16	16	16	16	16	16	17	15	16	16	16	16	16	16	16	16	16	1
Post. sp.	41	41	41	39	40	40	40	41	40	40	40	42	40	40	39	39	39	39	40	39	39	39	40	40	42	4
W. vert.	46	45	46	44	45	44	44	45	44	44	44	46	44	43	42	43	42	42	42	43	42	41	44	44	47	4
H. vert.	41	40	39	41	39	40	42	41	43	40	40	40	40	39	42	42	44	41	44	42	41	46	40	40	42	
Total segs.	67	65	66	65	65	64	65	66	66	64	64	66	64	63	63	64	64	63	64	64	63	64	64	64	68	

Individual	*273*	*274*	*275*	*276*	*277*	*278*	*279*	*280*	*281*	*282*	*283*	*284*	*285*	*286*	*287*	*288*	*289*	*290*	*291*	*292*	*293*	*294*	*295*	*296*	*297*	*29*
Sex	♂	♀	♂	♂	♀	♀	♂	♂	♀	♂	♀	♀	♀	♀	♀	♂	♀	♀	♀	♀	♂	♀	♂	♂	♂	
Ant. sp.	16	16	15	16	16	16	15	15-16	16	16	18	16	16	16	17	16	15	15	15	16	16	16	15	16	15	1
Post. sp.	40	41	42	42	42	41	42	39	40	40	41	40	41	40	41	41	40	41	40	40	39	41	41	40	40	4
W. vert.	45	45	46	47	46	45	46	43	45	44	46	46	46	45	46	45	45	45	44	43	44	44	45	44	44	4
H. vert.	39	44	44	40	40	42	40	40	37	39	40	38	40	38	39	41	38	40	41	41	40	41	39	40	40	
Total segs.	65	67	68	67	66	66	66	63	64	64	66	65	66	64	66	66	64	65	65	64	64	65	65	64	64	

Individual	*299*	*300*	*301*	*302*	*303*	*304*
Sex	♀	♂	♀	♂	♀	♂
Ant. sp.	16	15	16	16	16	16
Post. sp.	41	40	41	40	41	41
W. vert.	45	44	45	44	45	45
H. vert.	43	42	40	41	41	42
Total segs.	67	65	65	65	66	66

75–82	from	♀	*84*	*149–162*	from	♀	*86*	*211–222*	from	♀	*155*
83–92	,,	,,	*85*	*163–164*	,,	,,	(?)	*223–234*	,,	,,	*156*
93–105	,,	,,	*87*	*165–168*	,,	,,	(?)	*235–246*	,,	,,	*157*
106–107	,,	,,	*88*	*169–174*	,,	,,	*149*	*247–259*	,,	,,	*158*
108–113	,,	,,	*89*	*175–180*	,,	,,	*150*	*260–270*	,,	,,	*159*
114–123	,,	,,	*90*	*181–187*	,,	,,	*151*	*271–279*	,,	,,	*160*
124–132	,,	,,	*91*	*188–193*	,,	,,	*152*	*280–288*	,,	,,	*161*
133–139	,,	,,	*93*	*194–201*	,,	,,	*153*	*289–296*	,,	,,	*162*
140–148	,,	,,	*92*	*202–210*	,,	,,	*154*	*297–304*	,,	,,	*163*

TABLE 14.

Anterior spine	*14*	*15*	*16*	*17*	*18*	No.
♂ adults	—	21	60	15	2	*98*
♂ embryos	—	24	104	15	2	*145*
♀ adults	2	19	81	40	3	*145*
♀ embryos	—	22	107	29	1	*159*

		♂ adults	♂ embryos	♀ adults	♀ embryos
M.		15·979	15·965	16·159	16·056
P. E. M.	±	·046	·031	·040	·031
σ		·6697	·5544	·7208	·5854
P. E. σ	±	·0323	·0219	·0286	·0221
C. V.		4·19	3·47	4·46	3·65

TABLE 15.

Posterior spine	*38*	*39*	*40*	*41*	*42*	*43*	*44*	No.
♂ adults	—	10	41	37	9	3	—	*100*
♂ embryos	—	18	62	45	18	2	—	*145*
♀ adults	—	5	29	67	52	4	2	*159*
♀ embryos	1	8	60	63	25	2	—	*159*

		♂ adults	♂ embryos	♀ adults	♀ embryos
M.		40·540	40·476	41·170	40·686
P. E. M.	±	·060	·051	·048	·040
σ		·8879	·9103	·9057	·8625
P. E. σ	±	·0423	·0361	·0343	·0281
C. V.		2·19	2·24	2·20	2·12

TABLE 16.

WHOLE VERTEBRAE	*41*	*42*	*43*	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*	No.
♂ adults	—	1	15	32	32	15	3	2	—	—	—	*100*
♂ embryos	1	7	19	48	42	20	7	—	—	—	1	*145*
♀ adults	—	—	7	46	59	35	13	3	—	—	—	*163*
♀ embryos	—	1	19	50	51	30	7	1	—	—	—	*159*

		♂ adults	♂ embryos	♀ adults	♀ embryos
M.		44·620	44·510	45·061	44·723
P. E. M.	±	·077	·074	·056	·058
σ		1·1470	1·3189	1·0722	1·0926
P. E. σ	±	·0547	·0522	·0401	·0413
C. V.		2·57	2·96	2·38	2·44

TABLE 17.

HALF VERTEBRAE	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	No.
♂ adults	—	—	—	—	1	6	11	12	25	18	13	9	3	2	—	—	—	*100*
♂ embryos	1	—	—	—	3	5	18	26	43	18	18	7	4	1	1	—	—	*145*
♀ adults	—	—	—	—	2	12	16	26	29	34	27	13	1	1	1	—	1	*163*
♀ embryos	—	—	—	1	3	6	24	22	46	30	17	6	4	—	—	—	—	*159*

		♂ adults	♂ embryos	♀ adults	♀ embryos
M.		40·370	40·034	40·288	39·956
P. E. M.	±	·128	·107	·101	·091
σ		1·9008	1·9169	1·9209	1·7022
P. E. σ	±	·0907	·0759	·0718	·0644
C. V.		4·71	4·79	4·77	4·26

TABLE 18.

TOTAL SEGMENTS	62	63	64	65	66	67	68	No.
♂ adults	—	6	23	43	18	9	1	*100*
♂ embryos	1	21	40	49	25	7	2	*145*
♀ adults	—	2	24	65	44	23	5	*163*
♀ embryos	1	11	44	61	30	12	—	*159*

		♂ adults	♂ embryos	♀ adults	♀ embryos
M.		65·040	64·724	65·472	64·906
P. E. M.	±	·0707	·065	·055	·056
σ		1·0480	1·1536	1·0410	1·0449
P. E. σ	±	·0499	·0457	·0389	·0395
C. V.		1·612	1·782	1·590	1·610

TABLE 19.

COLLECTOR NERVES	4	5	6	7	No.
♂ adults	21	113	65	1	*200*
♀ adults	16	176	102	2	*296*

		♂ s	♀ s
M.		5·230	5·304
P. E. M.	±	·030	·024
σ		·6301	·6059
P. E. σ	±	·0212	·0168
C. V.		12·05	11·42

TABLE 20.

POST-GIRDLE NERVES	6	7	8	9	10	11	No.
♂ adults	—	1	18	102	66	13	*200*
♀ adults	7	71	163	49	6	—	*296*

		♂ s	♀ s
M.		9·360	7·920
P. E. M.	±	·039	·030
σ		·8188	·7580
P. E. σ	±	·0276	·0215
C. V.		8·748	9·570

TABLE 21.

1ST G.-P. NERVE	26	27	28	29	30	31	No.
♂ adults	2	19	84	77	14	4	*200*
♀ adults	—	6	58	149	79	4	*296*

		♂ s	♀ s
M.		28·470	29·057
P. E. M.	±	·041	·030
σ		·8713	·7712
P. E. σ	±	·0294	·0213
C. V.		3·060	2·654

TABLE 22. *Correlations between whole Vertebrae and posterior Spine.*

M.

	42	*43*	*44*	*45*	*46*	*47*	*48*	
39	—	5	3	2	—	—	—	10
40	1	9	20	10	1	—	—	41
41	—	1	8	20	8	—	—	37
42	—	—	1	—	6	2	—	9
43	—	—	—	—	—	1	2	3
	1	15	32	32	15	3	2	100

$r = \cdot 7317 \pm \cdot 0304$

F.

	43	*44*	*45*	*46*	*47*	*48*	
39	1	4	—	—	—	—	5
40	4	18	6	1	—	—	29
41	1	20	31	15	—	—	67
42	1	3	21	17	9	1	52
43	—	—	—	1	3	—	4
44	—	—	—	—	—	2	2
	7	45	58	34	12	3	159

$r = \cdot 6540 \pm \cdot 0297$

m.

	41	*42*	*43*	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*	
39	1	4	8	5	—	—	—	—	—	—	—	18
40	—	3	10	34	15	—	—	—	—	—	—	62
41	—	—	1	8	25	11	—	—	—	—	—	45
42	—	—	—	1	2	8	7	—	—	—	—	18
43	—	—	—	—	—	1	—	—	—	—	1	2
	1	7	19	48	42	20	7	—	—	—	1	145

$r = \cdot 7742 \pm \cdot 0218$

f.

	42	*43*	*44*	*45*	*46*	*47*	*48*	
38	—	1	—	—	—	—	—	1
39	1	4	2	1	—	—	—	8
40	—	14	31	12	3	—	—	60
41	—	—	16	31	15	1	—	63
42	—	—	1	7	12	4	1	25
43	—	—	—	—	—	2	—	2
	1	19	50	51	30	7	1	159

$r = \cdot 7219 \pm \cdot 0248$

TABLE 23. *Correlations between total Segments and posterior Spine.*

M.

	63	*64*	*65*	*66*	*67*	*68*	
39	3	5	2	—	—	—	10
40	2	13	21	5	—	—	41
41	1	5	19	10	2	—	37
42	—	—	1	3	5	—	9
43	—	—	—	—	2	1	3
	6	23	43	18	9	1	100

$r = \cdot 6753 \pm \cdot 0356$

F.

	63	*64*	*65*	*66*	*67*	*68*	
39	—	4	1	—	—	—	5
40	2	10	14	3	—	—	29
41	—	7	41	16	3	—	67
42	—	2	8	24	16	2	52
43	—	—	—	1	2	1	4
44	—	—	—	—	—	2	2
	2	23	64	44	21	5	159

$r = \cdot 6754 \pm \cdot 0282$

m.

	62	*63*	*64*	*65*	*66*	*67*	*68*	
39	1	8	6	3	—	—	—	18
40	—	13	25	21	3	—	—	62
41	—	—	8	20	16	1	—	45
42	—	—	1	5	6	4	2	18
43	—	—	—	—	—	2	—	2
	1	21	40	49	25	7	2	145

$r = \cdot 6832 \pm \cdot 0290$

f.

	62	*63*	*64*	*65*	*66*	*67*	
38	—	1	—	—	—	—	1
39	1	1	4	2	—	—	8
40	—	6	28	24	3	—	60
41	—	3	12	27	16	4	63
42	—	—	—	8	9	8	25
43	—	—	—	—	2	—	2
	1	11	44	61	30	12	159

$r = \cdot 5882 \pm \cdot 0316$

TABLE 24. *Correlations between total Segments and whole Vertebrae.*

M.

	63	*64*	*65*	*66*	*67*	*68*	
42	—	1	—	—	—	—	1
43	3	4	7	1	—	—	15
44	2	10	15	4	1	—	32
45	1	8	16	7	—	—	32
46	—	—	5	5	5	—	15
47	—	—	—	1	2	—	3
48	—	—	—	—	1	1	2
	6	23	43	18	9	1	100

$r = \cdot 5534 \pm \cdot 0454$

F.

	63	*64*	*65*	*66*	*67*	*68*	
43	—	4	1	1	1	—	7
44	2	13	27	4	—	—	46
45	—	5	24	20	9	1	59
46	—	2	13	12	8	—	35
47	—	—	—	7	4	2	13
48	—	—	—	—	1	2	3
	2	24	65	44	23	5	163

$r = \cdot 5660 \pm \cdot 0358$

m.

	62	*63*	*64*	*65*	*66*	*67*	*68*	
41	—	—	1	—	—	—	—	1
42	—	4	3	—	—	—	—	7
43	1	8	6	4	—	—	—	19
44	—	8	25	12	2	1	—	48
45	—	1	5	24	11	1	—	42
46	—	—	—	7	10	2	1	20
47	—	—	—	2	2	2	1	7
48	—	—	—	—	—	—	—	—
49	—	—	—	—	—	—	—	—
50	—	—	—	—	—	—	—	—
51	—	—	—	—	—	1	—	1
	1	21	40	49	25	7	2	145

$r = \cdot 6707 \pm \cdot 0299$

f.

	62	*63*	*64*	*65*	*66*	*67*	
42	1	—	—	—	—	—	1
43	—	7	10	2	—	—	19
44	—	2	22	22	4	—	50
45	—	2	12	24	9	4	51
46	—	—	—	12	12	6	30
47	—	—	—	1	4	2	7
48	—	—	—	—	1	—	1
	1	11	44	61	30	12	159

$r = \cdot 6492 \pm \cdot 0300$

Note. M above a table denotes adult ♂s, F = adult ♀s, m = ♂ embryos, and f = ♀ embryos.

TABLE 25. *Correlations between half and whole Vertebrae.*

M.

	36	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*	*45*	
42	—	—	—	—	—	—	—	1	—	—	1
43	—	—	—	—	3	2	2	6	1	1	15
44	—	1	1	5	5	10	5	2	2	1	32
45	1	1	7	3	13	4	3	—	—	—	32
46	—	3	2	3	2	2	3	—	—	—	15
47	—	—	1	—	2	—	—	—	—	—	3
48	—	1	—	1	—	—	—	—	—	—	2
	1	6	11	12	25	18	13	9	3	2	100

$r = - \cdot 5226 \pm \cdot 0476$

F.

	36	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	*47*	*48*	
43	—	—	—	—	—	3	1	1	—	1	—	—	1	7
44	—	—	2	5	8	11	16	3	1	—	—	—	—	46
45	—	2	3	10	14	14	6	9	—	—	1	—	—	59
46	2	8	5	8	4	5	3	—	—	—	—	—	—	35
47	—	1	6	2	2	1	1	—	—	—	—	—	—	13
48	—	1	—	1	1	—	—	—	—	—	—	—	—	3
	2	12	16	26	29	34	27	13	1	1	1	—	1	163

$r = - \cdot 4860 \pm \cdot 0392$

m.

	32…36	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	
41	—	—	—	—	—	—	—	—	—	—	—	1	1
42	—	—	—	—	—	—	2	2	—	3	—	—	7
43	—	—	—	1	1	7	2	4	4	—	—	—	19
44	—	—	—	8	6	19	7	5	2	—	1	—	48
45	—	1	3	2	11	13	7	4	1	—	—	—	42
46	—	—	2	5	7	3	—	2	—	1	—	—	20
47	—	2	—	2	1	1	—	1	—	—	—	—	7
48	—	—	—	—	—	—	—	—	—	—	—	—	—
49	—	—	—	—	—	—	—	—	—	—	—	—	—
50	—	—	—	—	—	—	—	—	—	—	—	—	—
51	1	—	—	—	—	—	—	—	—	—	—	—	1
	1	3	5	18	26	43	18	18	7	4	1	1	145

$r = - \cdot 5580 \pm \cdot 0374$

f.

	35	*36*	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*	
42	—	—	—	—	—	1	—	—	—	—	1
43	—	—	—	—	1	6	5	5	1	1	19
44	—	—	—	2	5	17	16	6	3	1	50
45	—	2	2	10	11	13	4	5	2	2	51
46	—	—	3	9	5	7	5	1	—	—	30
47	1	—	1	3	—	2	—	—	—	—	7
48	—	1	—	—	—	—	—	—	—	—	1
	1	3	6	24	22	46	30	17	6	4	159

$r = - \cdot 5028 \pm \cdot 0388$

TABLE 26. *Correlations between posterior and anterior Spines.*

M.

	39	*40*	*41*	*42*	*43*	
15	6	13	2	—	—	21
16	2	25	27	5	1	60
17	—	3	7	3	2	15
18	—	—	1	1	—	2
	8	41	37	9	3	98

$r = \cdot 5216 \pm \cdot 0485$

F.

	39	*40*	*41*	*42*	*43*	
14	1	—	1	—	—	2
15	2	10	7	—	—	19
16	1	16	38	26	—	81
17	—	3	18	16	3	40
18	—	—	—	2	1	3
	4	29	64	44	4	145

$r = \cdot 4828 \pm \cdot 0420$

m.

	39	*40*	*41*	*42*	*43*	
15	2	13	7	2	—	24
16	14	46	33	10	1	104
17	2	3	5	4	1	15
18	—	—	—	2	—	2
	18	62	45	18	2	145

$r = \cdot 2102 \pm \cdot 0524$

f.

	38	*39*	*40*	*41*	*42*	*43*	
15	—	3	13	5	1	—	22
16	1	5	40	42	18	1	107
17	—	—	7	15	6	1	29
18	—	—	—	1	—	—	1
	1	8	60	63	25	2	159

$r = \cdot 2719 \pm \cdot 0485$

TABLE 27. *Correlations between total Segments and half Vertebrae.*

M.

	63	64	65	66	67	68	
18	1	—	—	—	—	—	1
19	2	8	5	1	1	—	17
20	3	10	16	5	2	1	37
21	—	4	15	7	5	—	31
22	—	1	7	4	—	—	12
23	—	—	—	1	1	—	2
	6	23	43	18	9	1	100

$r = \cdot 3745 \pm \cdot 0563$

F.

	63	64	65	66	67	68	
18	—	2	—	—	—	—	2
19	2	5	13	7	1	—	28
20	—	13	24	12	4	2	55
21	—	4	27	20	8	2	61
22	—	—	1	4	9	—	14
23	—	—	—	1	—	1	2
24	—	—	—	—	1	—	1
	2	24	65	44	23	5	163

$r = \cdot 4397 \pm \cdot 0414$

m.

	62	63	64	65	66	67	68	
32	—	—	—	—	—	1	—	1
33	—	—	—	—	—	—	—	—
34	—	—	—	—	—	—	—	—
35	—	—	—	—	—	—	—	—
36	—	1	—	2	—	—	—	3
37	—	—	3	2	—	—	—	5
38	1	8	2	5	2	—	—	18
39	—	1	6	11	7	1	—	26
40	—	7	19	13	3	1	—	43
41	—	2	2	7	7	—	—	18
42	—	2	4	5	4	2	1	18
43	—	—	—	4	2	1	—	7
44	—	—	3	—	—	—	1	4
45	—	—	—	—	—	1	—	1
46	—	—	1	—	—	—	—	1
	1	21	40	49	25	7	2	145

$r = \cdot 1945 \pm \cdot 0523$

f.

	62	63	64	65	66	67	
35	—	—	—	1	—	—	1
36	—	2	—	—	1	—	3
37	—	—	2	3	1	—	6
38	—	2	10	9	3	—	24
39	—	1	5	11	5	—	22
40	1	6	17	13	7	2	46
41	—	—	5	16	4	5	30
42	—	—	5	6	5	1	17
43	—	—	—	1	3	2	6
44	—	—	—	1	1	2	4
	1	11	44	61	30	12	159

$r = \cdot 3266 \pm \cdot 0464$

TABLE 28. *Correlations between total Segments and anterior Spine.*

M.

	63	64	65	66	67	68	
15	2	7	9	3	—	—	21
16	4	10	27	11	8	—	60
17	—	5	5	3	1	1	15
18	—	—	1	1	—	—	2
	6	22	42	18	9	1	98

$r = \cdot 1544 \pm \cdot 0645$

F.

	63	64	65	66	67	68	
14	—	—	2	—	—	—	2
15	1	7	7	2	2	—	19
16	1	12	38	17	12	1	81
17	—	3	11	19	6	1	40
18	—	—	—	2	1	—	3
	2	22	58	40	21	2	145

$r = \cdot 328 \pm \cdot 0485$

m.

	62	63	64	65	66	67	68	
15	—	4	8	8	3	—	1	24
16	1	15	32	33	17	5	1	104
17	—	2	—	7	5	1	—	15
18	—	—	—	1	—	1	—	2
	1	21	40	49	25	7	2	145

$r = \cdot 1684 \pm \cdot 0528$

f.

	62	63	64	65	66	67	
15	—	4	6	10	1	1	22
16	1	4	32	46	18	6	107
17	—	3	6	5	10	5	29
18	—	—	—	—	1	—	1
	1	11	44	61	30	12	159

$r = \cdot 2246 \pm \cdot 0493$

TABLE 29. *Correlations between half Vertebrae and anterior Spine.*

M.

	18	19	20	21	22	23	
15	—	1	9	10	1	—	21
16	1	8	21	18	10	2	60
17	—	6	5	3	1	—	15
18	—	1	1	—	—	—	2
	1	16	36	31	12	2	98

$r = - \cdot 199 \pm \cdot 0635$

F.

	18	19	20	21	22	23	24	
14	—	—	1	1	—	—	—	2
15	—	4	6	5	3	1	—	19
16	2	15	24	32	8	—	—	81
17	—	5	15	17	2	—	1	40
18	—	1	—	2	—	—	—	3
	2	25	46	57	13	1	1	145

$r = \cdot 0031 \pm \cdot 0542$

m.

	16	17	18	19	20	21	22	23	
15	—	—	—	5	10	6	3	—	24
16	1	—	1	16	54	23	8	1	104
17	—	—	2	1	5	7	—	—	15
18	—	—	—	1	—	—	—	1	2
	1	—	3	23	69	36	11	2	145

$r = \cdot 0009 \pm \cdot 0543$

f.

	18	19	20	21	22	
15	—	1	12	9	—	22
16	3	24	42	29	9	107
17	1	5	13	9	1	29
18	—	—	1	—	—	1
	4	30	68	47	10	159

$r = - \cdot 068 \pm \cdot 0517$

TABLE 30.

Correlations between 1st Girdle-piercing Nerve and Post-girdle Nerves.

M.

	26	*27*	*28*	*29*	*30*	*31*	
7	—	—	—	—	1	—	1
8	—	—	1	10	3	4	18
9	—	—	38	54	10	—	102
10	—	10	43	13	—	—	66
11	2	9	2	—	—	—	13
	2	19	84	77	14	4	200

$r = -\cdot 6227 \pm \cdot 0283$

F.

	27	*28*	*29*	*30*	*31*	
6	—	—	—	5	2	7
7	—	—	35	35	1	71
8	2	26	97	37	1	163
9	2	28	17	2	—	49
10	2	4	—	—	—	6
	6	58	149	79	4	296

$r = -\cdot 5758 \pm \cdot 0254$

TABLE 31.

Correlations between 1st Girdle-piercing Nerve and posterior Spine.

M.

	26	*27*	*28*	*29*	*30*	*31*	
39	2	2	8	7	1	—	20
40	—	16	51	14	1	—	82
41	—	1	23	44	6	—	74
42	—	—	2	12	4	—	18
43	—	—	—	—	2	4	6
	2	19	84	77	14	4	200

$r = \cdot 5768 \pm \cdot 0309$

F.

	27	*28*	*29*	*30*	*31*	
39	—	7	3	—	—	10
40	2	26	24	—	—	52
41	4	17	69	28	—	118
42	—	8	48	40	—	96
43	—	—	—	6	2	8
44	—	—	—	2	2	4
	6	58	144	76	4	288

$r = \cdot 5398 \pm \cdot 0270$

TABLE 32.

Correlations between 1st Girdle-piercing Nerve and whole Vertebrae.

M.

	26	*27*	*28*	*29*	*30*	*31*	
42	—	2	—	—	—	—	2
43	2	6	16	5	1	—	30
44	—	8	41	15	—	—	64
45	—	1	22	36	5	—	64
46	—	2	5	19	4	—	30
47	—	—	—	2	3	1	6
48	—	—	—	—	1	3	4
	2	19	84	77	14	4	200

$r = \cdot 6181 \pm \cdot 0286$

F.

	27	*28*	*29*	*30*	*31*	
43	—	8	6	—	—	14
44	4	23	52	5	—	84
45	2	15	59	30	—	106
46	—	12	24	26	—	62
47	—	—	6	16	2	24
48	—	—	2	2	2	6
	6	58	149	79	4	296

$r = \cdot 4548 = \pm \cdot 0302$

TABLE 33.

Correlations between 1st Girdle-piercing Nerve and Collector Nerves.

M.

	26	*27*	*28*	*29*	*30*	*31*	
4	—	12	5	4	—	—	21
5	2	7	70	27	7	—	113
6	—	—	9	46	7	3	65
7	—	—	—	—	—	1	1
	2	19	84	77	14	4	200

$r = \cdot 5590 \pm \cdot 0318$

F.

	27	*28*	*29*	*30*	*31*	
4	—	12	4	—	—	16
5	6	36	101	33	—	176
6	—	10	44	44	4	102
7	—	—	—	2	—	2
	6	58	149	79	4	296

$r = \cdot 3821 \pm \cdot 0325$

TABLE 34.

Correlations between 1st Girdle-piercing Nerve and total Segments.

M.

	26	*27*	*28*	*29*	*30*	*31*	
63	2	4	4	2	—	—	12
64	—	6	24	16	—	—	46
65	—	9	41	32	4	—	86
66	—	—	12	18	6	—	36
67	—	—	3	9	4	2	18
68	—	—	—	—	—	2	2
	2	19	84	77	14	4	200

$r = {\cdot}5051 \pm {\cdot}0345$

F.

	27	*28*	*29*	*30*	*31*	
63	—	2	—	—	—	2
64	2	18	22	2	—	44
65	4	21	72	23	—	120
66	—	15	37	28	—	80
67	—	—	18	22	2	42
68	—	2	—	4	2	8
	6	58	149	79	4	296

$r = {\cdot}4253 \pm {\cdot}0312$

TABLE 35.

Correlations between total Segments and Collector Nerves.

M.

	63	*64*	*65*	*66*	*67*	*68*	
4	2	5	12	2	—	—	21
5	7	27	51	20	8	—	113
6	3	14	23	14	9	2	65
7	—	—	—	—	1	—	1
	12	46	86	36	18	2	200

$r = {\cdot}2056 \pm {\cdot}0443$

F.

	63	*64*	*65*	*66*	*67*	*68*	
4	—	3	6	5	—	2	16
5	2	28	74	50	22	—	176
6	—	13	39	25	19	6	102
7	—	—	1	—	1	—	2
	2	44	120	80	42	8	296

$r = {\cdot}102 \pm {\cdot}0376$

TABLE 36.

Correlation between number and proportional length of whole Vertebrae.

M.

	·605	*·615*	*·625*	*·635*	*·645*	*·655*	*·665*	*·675*	*·685*	*·695*	
43	1	1	2	4	1	—	—	—	—	—	9
44	—	1	4	2	5	7	1	—	—	—	20
45	—	—	1	2	2	2	4	—	—	1	12
46	—	—	—	1	3	3	2	—	2	—	11
47	—	—	—	—	—	—	1	—	—	—	1
48	—	—	—	—	—	—	1	1	—	—	2
	1	2	7	9	11	12	9	1	2	1	55

$r = {\cdot}5838 \pm {\cdot}0582$

TABLE 37.

Correlation between number of Fin Rays and Pelvic Nerves.

F.

	15	*16*	*17*	*18*	*19*	*20*	
12	—	2	9	4	—	—	15
13	5	13	13	15	3	2	51
14	1	5	8	4	3	—	21
15	—	—	2	1	2	—	5
	6	20	32	24	8	2	92

$r = {\cdot}058 \pm {\cdot}0680$

FRATERNAL CORRELATIONS.

TABLE 38.

Anterior Spine.

♂

	15	*16*	*17*	*18*	
15	12	34	5	—	51
16	34	258	47	4	343
17	5	47	24	—	76
18	—	4	—	—	4
	51	343	76	4	474

$r = \cdot 2543 \pm \cdot 0281$

♀

	15	*16*	*17*	*18*	
15	18	54	7	—	79
16	54	174	51	4	283
17	7	51	60	1	119
18	—	4	1	—	5
	79	283	119	5	486

$r = \cdot 3646 \pm \cdot 0257$

Siblings.

	15	*16*	*17*	*18*	
15	68	179	26	—	273
16	179	940	199	12	1330
17	26	199	130	7	362
18	—	12	7	—	19
	273	1330	362	19	1984

$r = \cdot 3085 \pm \cdot 0133$

TABLE 39.

Posterior Spine.

♂

	39	*40*	*41*	*42*	*43*	
39	34	18	2	—	—	54
40	18	80	76	26	2	202
41	2	76	46	19	4	147
42	—	26	19	16	2	63
43	—	2	4	2	—	8
	54	202	147	63	8	474

$r = \cdot 3863 \pm \cdot 0256$

♀

	39	*40*	*41*	*42*	
39	2	19	9	1	31
40	19	80	75	16	190
41	9	75	66	34	184
42	1	16	34	30	81
	31	190	184	81	486

$r = \cdot 3330 \pm \cdot 0264$

Siblings.

	39	*40*	*41*	*42*	*43*	
39	66	112	29	3	—	210
40	112	352	294	78	3	839
41	29	294	220	106	5	654
42	3	78	106	78	4	269
43	—	3	5	4	—	12
	210	839	654	269	12	1984

$r = \cdot 3732 \pm \cdot 0126$

TABLE 40.

Whole Vertebrae.

♂

	41	*42*	*43*	*44*	*45*	*46*	*47*	
41	—	5	—	—	—	—	—	5
42	5	20	—	—	—	—	—	25
43	—	—	4	17	9	6	—	36
44	—	—	17	44	38	21	3	123
45	—	—	9	38	78	38	9	172
46	—	—	6	21	38	18	8	91
47	—	—	—	3	9	8	2	22
	5	25	36	123	172	91	22	474

$r = \cdot 5407 \pm \cdot 0213$

♀

	43	*44*	*45*	*46*	*47*	
43	14	19	10	3	—	46
44	19	56	42	27	1	145
45	10	42	60	48	3	163
46	3	27	48	40	5	123
47	—	1	3	5	—	9
	46	145	163	123	9	486

$r = \cdot 3711 \pm \cdot 0256$

Siblings.

	41	*42*	*43*	*44*	*45*	*46*	*47*	
41	—	5	3	2	—	—	—	10
42	5	20	15	11	—	—	—	51
43	3	15	30	75	38	26	1	188
44	2	11	75	228	183	94	5	598
45	—	—	38	183	264	160	23	668
46	—	—	26	94	160	114	20	414
47	—	—	1	5	23	20	6	55
	10	51	188	598	668	414	55	1984

$r = \cdot 4049 \pm \cdot 0123$

These tables are to be read thus: There were 51 pairs of brothers with anterior spine at the 15th vertebra in the case of one of the pair, the other brother had the anterior spine at 15 in 12 cases, at 16 in 34 cases and at 17 in 5 cases; and so on.

TABLE 41.

Half Vertebrae.

♂

	36	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	
36	—	—	2	2	3	1	—	1	—	—	—	9
37	—	6	3	7	1	5	—	—	—	—	—	22
38	2	3	4	9	8	11	3	3	—	—	—	43
39	2	7	9	14	31	12	13	2	1	—	—	91
40	3	1	8	31	44	13	21	5	2	—	—	128
41	1	5	11	12	13	14	10	2	4	—	2	74
42	—	—	3	13	21	10	10	6	3	—	—	67
43	1	—	3	2	5	2	6	2	—	—	—	21
44	—	—	—	1	2	4	3	—	2	—	2	14
45	—	—	—	—	—	—	—	—	—	—	—	—
46	—	—	—	—	—	2	1	—	2	—	—	5
	9	22	43	91	128	74	67	21	14	—	5	474

$r = \cdot 2621 \pm \cdot 0352$

♀

	37	*38*	*39*	*40*	*41*	*42*	*43*	*44*	
37	2	6	9	5	1	—	—	—	23
38	6	6	16	13	11	3	1	1	57
39	9	16	20	24	10	5	3	—	87
40	5	13	24	24	37	21	7	4	135
41	1	11	10	37	24	14	7	1	105
42	—	3	5	21	14	2	3	2	50
43	—	1	3	7	7	3	—	—	21
44	—	1	—	4	1	2	—	—	8
	23	57	87	135	105	50	21	8	486

$r = \cdot 2771 \pm \cdot 0268$

Siblings.

	36	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	
36	—	1	4	6	4	1	1	1	—	—	—	18
37	1	8	14	19	21	9	—	1	1	—	—	74
38	4	14	26	50	52	43	14	6	1	—	—	210
39	6	19	50	52	112	55	35	15	6	—	1	351
40	4	21	52	112	159	103	81	27	15	—	2	576
41	1	9	43	55	103	59	52	20	6	—	2	350
42	1	—	14	35	81	52	36	18	11	—	3	251
43	1	1	6	15	27	20	18	8	1	—	—	97
44	—	1	1	6	15	6	11	1	4	—	2	47
45	—	—	—	—	—	—	—	—	—	—	—	—
46	—	—	—	1	2	2	3	—	2	—	—	10
	18	74	210	351	576	350	251	97	47	—	10	1984

$r = \cdot 2313 \pm \cdot 0139$

TABLE 42.

Total Segments.

♂

	63	*64*	*65*	*66*	*67*	*68*	
63	12	24	12	4	—	—	50
64	22	24	30	18	1	—	95
65	12	30	80	52	13	2	189
66	4	18	52	16	11	2	103
67	—	1	13	11	2	2	29
68	—	—	2	2	2	2	8
	50	95	189	103	29	8	474

$r = \cdot 3950 \pm \cdot 0254$

♀

	63	*64*	*65*	*66*	*67*	
63	2	13	6	3	—	24
64	13	32	44	22	2	113
65	6	44	98	41	11	200
66	3	22	41	20	14	100
67	—	2	11	14	22	49
	24	113	200	100	49	486

$r = \cdot 4101 \pm \cdot 0247$

Siblings.

	63	*64*	*65*	*66*	*67*	*68*	
63	36	73	41	15	1	—	166
64	73	144	164	73	10	—	464
65	41	164	364	175	43	2	789
66	15	73	175	80	46	6	395
67	1	10	43	46	48	6	154
68	—	—	2	6	6	2	16
	166	464	789	395	154	16	1984

$r = \cdot 4285 \pm \cdot 0120$

PARENTAL CORRELATIONS.

TABLE 43.

Anterior Spine.

Mother

Offspring.	15	16	17	
15	6	16	12	34
16	23	77	53	153
17	—	4	31	35
18	—	1	1	2
	29	98	97	224

$r = \cdot 359 \pm \cdot 039$

TABLE 44.

Whole Vertebrae.

Mother.

Offspring.	44	45	46	47	
41	—	—	1	—	1
42	—	—	5	—	5
43	7	11	7	—	25
44	17	24	17	—	58
45	20	26	26	3	75
46	8	11	22	3	44
47	1	—	2	3	6
	53	72	80	9	224

$r = \cdot 168 \pm \cdot 044$

TABLE 45.

Posterior Spine.

Mother.

Offspring.	39	40	41	42	
39	1	1	12	7	21
40	5	12	65	12	94
41	1	9	51	17	78
42	—	4	10	16	30
43	—	—	—	1	1
	7	26	138	53	224

$r = \cdot 196 \pm \cdot 043$

TABLE 46.

Half Vertebrae.

Mother.

Offspring.	37	38	39	40	41	42	43	
36	1	—	—	—	—	1	—	2
37	4	4	1	—	—	—	—	9
38	5	5	6	2	2	3	1	24
39	8	6	2	7	9	6	1	39
40	6	7	10	13	14	12	3	65
41	2	2	10	7	10	5	3	39
42	—	—	5	9	7	6	—	27
43	3	—	2	1	5	1	—	12
44	—	1	1	2	2	—	—	6
45	—	—	—	—	—	—	—	—
46	—	—	—	1	—	—	—	1
	29	25	37	42	49	34	8	224

$r = \cdot 238 \pm \cdot 042$

TABLE 47.

Total Segments.

Mother.

Offspring.	63	64	65	66	67	68	
63	—	6	7	6	—	—	19
64	—	11	25	17	1	—	54
65	6	8	42	29	5	1	91
66	—	7	14	13	6	3	43
67	—	1	—	3	8	3	15
68	—	—	—	—	—	2	2
	6	33	88	68	20	9	224

$r = \cdot 416 \pm \cdot 037$

Note on Mr Punnett's Section on the Inheritance of Meristic Characters.

BY KARL PEARSON.

I should like to add a few words (as he himself has suggested) as to the results of this portion of Mr Punnett's investigation. I feel the more anxious to do so because he has broken entirely new ground, which we can only hope will attract the attention it deserves, and so bring new workers to this field. If so, it is desirable to state the conditions under which it is possible to obtain final results. The father in the case chosen by Mr Punnett is quite unknown, hence it is absolutely needful, in order to reach accurate values of the correlation, that we should have enough mothers of each class to insure that the average father of that class is practically the average father of the population. When Mr Punnett first sent me material for reduction it consisted of 88 individuals forming 10 families for maternal correlation, and 93 individuals in 12 families for fraternal correlation. Allowing for four to five classes in the tables, it was obvious that the extreme arrays of offspring would be due to one, or at most two mothers. It was not likely, therefore, that the mean father of these groups would be the mean father of the general population. However, we ventured to reduce the data with the following results :—

Correlations.

Series I.	88 Individuals in 10 Families		93 Individuals in 12 Families		
Character	Parental Correlations		Fraternal Correlations		
	Raw Value	Corrected Value (a)	Raw Value	Corrected (a)	Corrected (b)
Posterior spine ...	·440 ± ·058	·534	·150 ± ·023	·246	·342
Anterior spine ...	·404 ± ·060	·444	·488 ± ·018	·509	·530
Whole vertebrae ...	·369 ± ·062	·467	·297 ± ·022	·364	·431
Half vertebrae ...	·225 ± ·068	·281	·152 ± ·023	·177	·203
Total segments ...	·534 ± ·051	·706	·294 ± ·022	·504	·714
Mean ...	·396	·486	·276	·360	·444

(a) Corrected for selection of mothers out of adult ♀ population.

(b) Corrected for selection of fathers also, on assumption that they were equally selected with mothers, although unknown.

Corrections made in the manner indicated *Phil. Trans.* Vol. 200, A, pp. 39—45.

Now it will be seen at once that the average corrected parental correlation, i.e. ·49, is in essential agreement—not with the ancestral law which fixes no value for the correlation—but with the values we have found for man, horse, and dog. On the other hand the fraternal correlation is very low, ·44 or even ·36, a value lower than we have yet found for any *physical* character in a *long* series of mammals. I told Mr Punnett that this value alone seemed sufficient to show that the material was inadequate. He then added 136 individuals in 15 families. They gave :

Series II.	136 Individuals in 15 Families		136 Individuals in 15 Families		
Character	Parental Correlations		Fraternal Correlations		
	Raw Value	Corrected Value (a)	Raw Value	Corrected (a)	Corrected (b)
Posterior spine ...	·096±·057	·142	·473±·015	·479	·484
Anterior spine ...	·357±·050	·396	·269±·018	·294	·318
Whole vertebrae ...	·139±·057	·177	·469±·015	·475	·482
Half vertebrae ...	·232±·055	·252	·238±·019	·246	·253
Total segments ...	·379±·050	·332	·477±·015	·457	·437
Mean ...	·241	·260	·385	·390	·395

The results were now much lower for the parental correlations, and slightly lower for the fraternal correlations. The differences between the two sets are in a number of cases significant compared with the probable error of the differences, and the only safe conclusion to be drawn is that the two samples from two different years are not *random* samples of the same population. Mr Punnett tells me that he cannot fix on any difference in the method of collecting or observing the two series. Judging by p. 321 one appears to have been procured at a rather earlier date than the other. Clubbing the two sets together we had the values for fraternal and parental correlation given in Mr Punnett's Tables 8 and 9. These arise from 224 individuals in 25 families for the parental, and 229 individuals in 27 families for fraternal values. The general result is, as we might expect, midway between the two.

Can we venture to draw any definite conclusions from these divergent values, and, if so, what?

Now, I think we may safely say that Mr Punnett has demonstrated the existence of inheritance in these meristic characters ; but that the paucity of material does not allow us to definitely fix its intensity.

The values found are very similar in intensity to those first found for stature in man from Mr Galton's material, mothers and sons ·302, mothers and daughters ·284*. These were based on 200 families. Again from the same data : Brother and brother = ·391, sister and sister ·444, sister and brother ·375. On Mr Galton's hypothesis the ancestral law gives for parental correlation ·300, and for fraternal ·400†. Or, we might even say that Mr Punnett's fish results agree on the average fairly well with those of Mr Galton for stature, and confirm his view of the ancestral law‡.

But this is, I take it, to miss the real point at issue. Such low values as Mr Punnett finds have been found before in man, in lepidoptera, and in molluscs, but in all these cases in short and doubtful series. They tell neither for nor against the ancestral law, but they are opposed to any hypothesis as to sensibly equal parental correlation in different species and for a variety of characters. That is a very vital point which no one can at present consider finally settled.

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* *Phil. Trans.* A, Vol. 187, p. 270 and p. 281.

† *R. S. Proc.* Vol. 62, pp. 397 and 410.

‡ Similarly we have for a short series of 100 families, the inheritance of cephalic index, mothers and daughters ·300 and brothers and sisters ·340, for example. *R. S. Proc.* Vol. 62, p. 415.

Still in long series for a variety of characters in man, horse, and dog the parental correlation certainly approaches a value about ·5. If Mr Punnett's values were for a long series I think we should have to conclude that the intensity of heredity could vary very much from species to species, and perhaps admit even considerable variation in the same species for the same character at different periods. Hitherto, however, we have found that when we replace our short and doubtful series by longer and more carefully measured or observed data—as we have done in several of the cases referred to above—we approach closer to the value ·5 for parental heredity. Further, the confirmation of Mr Punnett's statements on p. 333, as to growth changes in post-embryonic life (and perhaps during embryonic life itself?) would certainly lead us to expect a weakened parental correlation (and in the latter case a weakened fraternal correlation). Anyhow values like ·3 for parental and ·4 for fraternal correlation cannot discriminate between the ancestral law and any form of Mendelian theory, for the former with Mr Galton's value of the constants actually leads to these values. A value like ·5 would be opposed to *one* fairly comprehensive Mendelian theory, but possibly not to every such theory.

A possible test between the ancestral law and my generalized Mendelian theory is given in my paper: *On a Criterion which may serve to test various Theories of Inheritance*[*]. It is there indicated that we should expect the variability of the several arrays in the latter case to be given by a parabola, while with anything like a normal distribution of variations it would in the former case be a straight line. Dr Lee and I applied this test to Mr Punnett's five parental correlation tables, we calculated the S.D.'s of each array and plotted them to the magnitude of the parental character. But the numbers in the arrays were so small, and therefore their probable errors so large, and there were so few points (especially if we omitted those which belonged to arrays of 6 to 10 members only, and therefore were absolutely untrustworthy), that we got nothing but wild zigzags of three to four lines; these differed between the wide limits of random sampling from neither straight line nor parabola, and were quite insufficient to serve as any criterion. In fact they only again emphasized the lesson we had already learnt from short series that 25, 50, or even 100 families are insufficient to adequately determine the biometric constants of a correlation surface for heredity. In saying this I do not for a moment undervalue the importance of Mr Punnett's work; he has shown for the first time how heredity in one species of fish can be dealt with, and this is a great step onwards. I quite realize the difficulty of dealing with 1000 mothers, but this is, I believe, the sort of ideal we must biometrically propose if we are to reach data sufficiently smooth to give final values to the heredity coefficients, and so available for testing between current theories.

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[*] *R. S. Proc.* Vol. 73, pp. 262—80.

ON THE MEASUREMENT OF INTERNAL CAPACITY FROM CRANIAL CIRCUMFERENCES.

By M. A. LEWENZ, M.A., and KARL PEARSON, F.R.S.

(1) In a memoir by Dr Alice Lee* on the reconstruction of the capacity of the skull from external measurements the following results were obtained:

(*a*) Equations giving the probable capacity of the skull from a knowledge of the length, breadth and height for a number of races.

(*b*) Equations giving the probable capacity from a knowledge of the product of length, breadth and height.

(*c*) A demonstration of the small relationship between capacity and cephalic index.

(*d*) A demonstration that the relationship between capacity and both horizontal and vertical circumferences varied much from race to race, even between allied races.

The conclusions drawn from these results were:

(i) That on the data dealt with there was no means of getting a small probable error in predicting the capacity of an individual skull from external measurements, but good results might be found from the average of series.

(ii) That (*b*) gave a formula which changed less from race to race than (*a*), and the mean formula from (*b*) gave reasonably close results when we paid attention to sex difference.

(iii) That the formula for the nearest allied race should, where possible, be selected, and failing any knowledge of evolutionary history then the mean formula based on (*b*).

It will be clear that the above results emphasise the need for judicious caution in using the cranial capacity formulae, and also offer hints from experience to those anxious to discover new formulae.

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* *Phil. Trans.* Vol. 196, A, pp. 225—264.

(2) Dr J. Beddoe has recently taken up the relation of skull capacity to cranial circumferences and published* new formulae connecting the capacity with the product of three such circumferences. Dr Beddoe is a veteran who has done such good service in creating interest in anthropometric matters, that we should hardly have noticed his paper hostilely here, had he not (*a*) shown in it a complete ignorance of the nature of modern statistical theory, and (*b*) misinterpreted partly through misunderstanding and partly through faulty arithmetic Dr Lee's results.

There is absolutely no reason why the product of three cranial circumferences should not be taken as a basis for estimating the capacity of the skull, but there is only one scientific way of reaching a suitable formula and that Dr Beddoe has not adopted.

We will point out what considerations must guide us in the matter. Let us take first the following three circumferences of the *Frankfurter Verständigung*, U = horizontal circumference, S = sagittal circumference from nasion to opisthion, Q = transverse circumference from the top of one auricular passage to the top of the other in the vertical plane, i.e. the plane which is perpendicular to the "horizontal plane," and does not generally pass through the bregma. Let C be the capacity, and $P = U \times S \times Q$, then we require to find a relation between C and P. In order to do this we must measure C and P for as many skulls of one sex and race as possible and then for as many races as possible to see how our formula changes with race.

The process may be illustrated as follows. We take 164 Theban mummy skulls and pick out all those with C lying between 1380 and 1390 cubic centimetres. This is a group well within the probable error of capacity determination. We have 10 such skulls with the values for P in cubic centimetres given below. Now 10 cubic centimetres is about 1/11 of the standard deviation in capacity and we may take 500 cubic centimetres to be very roughly the same proportion of the variability of P. Picking out all the P's from 58,600 to 59,100 we have the following system:

	Capacities from 1380—1390		P from 58,600 to 59,100
Values of P in cms.^{3}	53,407	Values of C in cms.^{3}	1310
	54,432		1353
	54,568		1355
	57,652		1360
	58,892		1365
	59,669		1380
	60,194		1426
	60,277		1430
	60,596		1437
	62,390		1470
Mean	58,208	Mean	1389

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* "De l'Évaluation et de la Signification de la Capacité cranienne," *L'Anthropologie*, Vol. XIV. pp. 267—294, 1903.

Now it will be seen at once from these results that to say a skull has a certain capacity does not fix the product of the circumferences, and to say that it has a certain product of circumferences by no means fixes its capacity. The only thing that is possible for us to assert is that Theban skulls with a capacity of 1380—90 will cluster round the value 58,208 of the circumference product, and skulls with a circumference product between 58,600 and 59,100 will cluster round the capacity value 1389. If these clusters follow—and they do follow—the usual distribution of characters in man, then these mean values are the "most probable values" for product or capacity when deduced from a knowledge of capacity or product respectively. Tables can now be dressed giving these "most probable values" for each small range of capacity or product. Such tables are only another form of the correlation table and the regression curve, which Dr Beddoe seems to find so mysterious; they are the only scientific way in 1904 of approaching these questions. Such "most probable values" in the case of most characters in man are found—allowing for the errors of random sampling—to increase uniformly with the uniform increase of the known character, in other words the regression curve is usually a straight line. The equation to this straight line is found by perfectly easy mathematical work and is what Dr Lee gave in her paper for the product of the three diameters, and what we give in this paper for the product of the three circumferences. If such a *linear* formula is to be used at all this is the only scientific way of approaching the problem. Dr Beddoe himself uses such a linear relation, B_1; yet how does he write of the only method of scientifically dealing with a perfectly elementary statistical problem?

"Je me reconnais incompétent pour décider si l'idée de corrélation peut tromper quand il s'agit de la forme cranienne et de sa capacité, et si l'idée de compensation, moins distinctement appréciable, il est vrai, mérite d'être étudiée[*]."

We assert, with a distinct appreciation of the seriousness of the statement, that a writer who cannot realise what correlation is and how it is used in a simple problem of this kind has no right nowadays to deal with craniometric problems at all. It is only by frankly asserting on every occasion this truth that we can hope to render anthropometry in all its branches a real science. The day for the old methods is once and for ever gone. Correlation is simply the mathematical process of finding the best linear relation between the known value of one character and the most probable value of a second. It determines in the special case A and B in the relation:

$$\text{Probable } C = A + B \times \text{Known } P \text{..........................(i).}$$

Dr Beddoe also wants to find a linear relation between Probable C and a Known P. How does he proceed? In no case does he go through the laborious and necessary work of tabling the mean C for a given small range of P. He simply puts:

$$\text{Probable } C = B \times \text{Known } P \text{ ....(ii),}$$

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[*] *Loc. cit.* p. 278.

and *guesses* what he considers a suitable value for B! He therefore (1) assumes that his line holds far beyond the range of any actual observation[*], for his only ground for putting $A=0$ must be, although he does not state it, that C vanishes with P; (2) neglects the result of all observations hitherto made on human characters, for in no case, that we are aware of—and certainly more than 100 must now have been worked out—is $A=0$. When Dr Beddoe does not guess B he obtains its value by giving C and P their mean values. Even here as he does not know the mean value of C, he guesses it!

"Je suis bien certain que la moyenne des pesées de cerveaux d'Anglais est un peu au dessous de 1400 grammes et que la moyenne de la capacité de crânes masculins anglais est voisine de 1500 c.c.[†]"

The only reasonably long series of English skulls with which we are acquainted neither give a mean of 1500. This is the type of guesswork which has hitherto passed for science in anthropometry. Even if Dr Beddoe had found by actually examining data that a formula

$$\text{Probable } C = B \times \text{Known } P$$

held for the skulls of one race, he ought before adopting it generally to have noted Dr Lee's warning about the changing degree of correlation between circumferences and capacity when we pass from one race to a closely allied race, and accordingly have tested it on other races. He has not attempted this, but finding it did not agree very well with observations on individuals attempted to modify it by introducing corrections depending on the cephalic index. This he has done notwithstanding Dr Lee's result that there is generally little correlation between cephalic index and capacity, and that what there is *varies largely from race to race*[‡].

(3) We now turn to our own contribution to the subject. Dealing with the three circumferences U, S, Q defined above, which differ somewhat from Dr Beddoe's three, we have sought a linear relationship between their product P and the mean value of the corresponding C for four different races. We have used the following male crania:

(*a*) Fawcett's measurements on 98 Naqada crania.
(*b*) E. Schmidt's measurements on 164 Theban mummies.
(*c*) Ranke's measurements on 78 Altbaierisch crania.
(*d*) Macdonell's measurements[§] on 72 English crania,

and we have one series for female crania,

(*e*) Macdonell's measurements on 76 English crania.

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[*] While the relation of the characters in man is closely linear for the range found in normal individuals of one race, it certainly ceases to be linear when we pass to 'dwarfs' and 'giants.' See Pearson: *Phil. Trans.* Vol. 192, A, pp. 169—214. There is no reason whatever for extending the linear relation like (i) to extreme 'dwarfs' and putting $A=0$.

[†] *Loc. cit.* 285.

[‡] See *loc. cit.* p. 233.

[§] We have heartily to thank Dr Macdonell for providing us not only with the data, but the actual reductions in cases (*d*) and (*e*). His own memoir on the English skull appeared in *Biometrika*, Vol. III. pp. 191—244.

The following results were obtained:

TABLE I.

Race	Mean C	Mean P	σ_C	σ_P	r_{CP}
(*a*) Naqada ♂ ...	1375	57,414	108·52	4412	·7492
(*b*) Theban ♂ ...	1388	58,285	118·01	4863	·8576
(*c*) German ♂ ...	1506	64,604	111·54	4997	·8587
(*d*) English ♂ ...	1477	60,860	122·37	5206	·8790
(*e*) English ♀ ...	1300	53,656	112·80	5157	·8860

From these results the following equations flow:

$$\left.\begin{array}{llll}(a) & \text{Naqada} & \male & \text{Probable } C = 317{\cdot}2 + {\cdot}01843P \\ (b) & \text{Theban} & \male & \text{Probable } C = 174{\cdot}7 + {\cdot}02081P \\ (c) & \text{German} & \male & \text{Probable } C = 267{\cdot}4 + {\cdot}01917P \\ (d) & \text{English} & \male & \text{Probable } C = 219{\cdot}2 + {\cdot}02067P \\ (e) & \text{English} & \female & \text{Probable } C = 263{\cdot}9 + {\cdot}01913P \end{array}\right\} \begin{array}{c} C \text{ and } P \text{ being} \\ \text{measured in cm.}^3 \end{array}$$

Now from these equations certain results at once flow. It is clear:

(i) That it is absolutely illegitimate to assume like Dr Beddoe that $A = 0$.

(ii) That A varies widely with race and sex, while B varies much less markedly, but possibly significantly. This is precisely what we might expect had racial differentiation arisen by selection from a common stock.

Thus Dr Lee's statement that the capacity and circumferences correlations varied so much between closely allied races that we could hardly expect to deduce a formula true for all races is fully borne out, when we investigate the relation between capacity and the circumference product. Dr Lee, after showing that the capacity and horizontal and vertical circumference correlations and regression equations varied from race to race, remarked: "We conclude therefore that it appears unlikely that a reconstruction formula, based on the circumferential measurements of the skull, can be found which will give good results, if extended from one local race to another*."

Dr Beddoe has apparently quite misunderstood the nature of the argument and simply dismisses the difficulty without meeting it with the words: "Le Dr Lee a fait des expériences sur l'arc transverse, mais elle a négligé l'arc sagittal, et ses résultats ne sont guère satisfaisants†."

Dr Lee's series seem sufficient for her purpose; it is the fact that they are sufficient but not satisfactory, which Dr Beddoe has no right to shirk.

If the reader will compare the above male formulae with those obtained for three races between the capacity and the diameters' product by Dr Lee‡, he will

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[*] See *loc. cit.* p. 263.

[†] *Loc. cit.* p. 269. Dr Lee used *two* arcs, not merely one as is suggested.

[‡] See *loc. cit.* p. 243.

at once realise why Dr Lee considered a diametral product formula could be better extended from one local race to another than a multiple regression circumference formula. She did not attempt a product circumference formula.

In view of the fact that our formulae vary so with race, it is venturesome to form a mean equation and treat it as an "inter-racial formula," but for comparison with Dr Beddoe's results it is perhaps desirable to do so*. We have as mean formula for males:

$$\text{Probable } C = 244{\cdot}6 + {\cdot}01977\, P \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (f).$$

We would only warn our readers to use such a formula with caution. For example, never to use it for females, and only in preference to one of the above four formulae when no evolutionary race relationship can be predicted between the above races and the race to be investigated.

We now turn to the probable error of these results. We have:

Probable Error of Individual Prediction.

Formula	(a)	(b)	(c)	(d)	(e)	Mean
Probable Error ...	48	41	39	39	35	40·4

To test the value of these results, 15 ♂ skulls (as nearly as possible every thirtieth skull) were taken at random from the Naqada measurements; 15 ♂ skulls from the Theban records (as nearly as possible each tenth skull), and similarly 15 from the Altbaierisch series. In the case of the Naqada crania 8 had an error greater and 7 less than the probable error; in the case of the Theban the numbers were 6 greater and 9 less, and for the Altbaierisch 9 greater and 6 less; or total 23 greater and 22 less than the probable error, which may be considered very satisfactory. The mean error of the 45 skulls as found from the mean formula is 47·5, corresponding to a probable error of $47{\cdot}5 \times {\cdot}8454 = 40{\cdot}2$. The theoretical value of this probable error is 40·4. There can therefore be, we think, small doubt that our mean formula will predict the capacity of a single *individual* skull from circumferential measurements with a probable error of about 40 cubic centimetres. Dr Lee's diametral product formula† showed a probable error of 43 for Aino ♂s, 55 for German ♂s and 52 for Naqada ♂s, say a mean value of 50. Actual application to 80 crania gave only a mean error of 49, or a probable error of about 42. Thus we should expect the present formulae to give slightly better results than the diameter product formulae, but for reasons to be given later we hold them quite inferior to those formulae for the living head.

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* A more correctly *inter-racial* result is given on p. 386 below. The above is really a mean *intra-racial* result.

† See *loc. cit.* pp. 234–7.

(4) We now turn to Dr Beddoe's rule B_3, which up to the date of writing this he considers his best formula *.

If we put Dr Beddoe's rule into a formula it is, if C be the capacity in cubic centimetres:

$$C = \left(1 + \frac{1}{300}(I - 80)\right) \frac{U \times S' \times Q'}{36000},$$

where I is the cephalic index, U is the horizontal circumference, Q' is the auricular circumference from the *centre* of one auricular passage to that of the other, and S' the sagittal arc from nasion to inion, all in millimetres.

It may be written in the form:

$$C = {\cdot}0000926\, I \times U \times S' \times Q' + {\cdot}020374\, U \times S' \times Q',$$

where the product $U \times S' \times Q'$ is to be read in cubic centimetres and not cubic millimetres.

Now let p_1 stand for $U \times S' \times Q'$ and p_2 for $I \times U \times S' \times Q'$, and let σ_v be the standard deviation of the character or quantity v and r_{vw} the correlation of the two quantities or characters v and w; then the proper formula for Dr Beddoe to have taken would have been:

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* Dr Beddoe gives three formula in his paper B_1, B_2, B_3, and calculates some of the results by one and some by another of these rules. He tells us that he has another rule B_4 in preparation, and that he has been gradually feeling his way. It is against any such process as this that we wish emphatically to protest. Every one of Dr Beddoe's formulae is a mere guess. In no case does he adopt a certain type of formula and determine by recognised statistical methods the best values to be given to the constants of that formula. If he finds it gives him somewhat too high a series of values he merely reduces it by cutting off a series of percentages from the result. As he tells us B_3 is his best formula at present we have used B_3. This is designed to give what Dr Beddoe terms Flower's values, or what we should simply term the capacities properly measured, e.g. not the recognised erroneous values of Barnard Davis. It is obtained in the following manner: he measured his sagittal arc, S', from the nasion to the inion instead of to the opisthion—of this later more—and since the sagittal arc, S', is usually measured to the opisthion, he subtracts 50 mm. from it to find S'. Next he takes the vertical circumference, Q', which he measures from the *centre* of one auricular passage to that of the other. This is really not our Q. Our transverse circumference is measured from *top* of one auricular passage to the top of the other and "vertical," i.e. perpendicular to the Frankfurt "horizontal plane." He ought not accordingly to have interchanged as he has done our Q with his own Q'. Probably 9 or 10 mm. ought to be subtracted to get Q from Q', even if we could possibly accept his "passant par le bregma ou pas loin en arrière" as giving even an approximation to the "vertical plane." But as Dr Beddoe appears content to use our Q for his Q', we have made no attempt to modify it in order to reach an arc so vaguely described as "passing through the bregma or not far behind it." As a matter of fact the "vertical plane" may easily fall 10, 20, or even 30 mm. behind it. Lastly, to get the capacity Dr Beddoe multiplies $\frac{1}{3}$ of the horizontal circumference (U) by $\frac{1}{3}$ of the nasio-iniac arc S' by $\frac{1}{2}$ of his auricular arc. He then divides this product by $\frac{1}{2000}$, and deducts $\frac{1}{3}$ per cent. of the result for each unit of the cephalic index below 80, and adds a third per cent. for each unit above 80. This is the rule which we have represented by the formula in the text. It will be observed that it is by no means so simple as the product formulae we have used, besides being obtained by a theoretically unjustifiable process. B_1 takes 45 mm., not 50 mm., off S to get S' and neglects the cephalic index correction. B_2 takes 50 mm. off like B_3, but takes $\frac{1}{2}$ instead of $\frac{1}{3}$ per cent. for cephalic index correction. It will be seen that the constants are pure guesswork changeable at will.

$$C - m_c = \frac{r_{cp_1} - r_{cp_2} r_{p_1p_2}}{\sqrt{1 - r^2_{p_1p_2}}} \frac{\sigma_c}{\sigma_{p_1}} (p_1 - m_{p_1}) + \frac{r_{cp_2} - r_{cp_1} r_{p_1p_2}}{\sqrt{1 - r^2_{p_1p_2}}} \frac{\sigma_c}{\sigma_{p_2}} (p_2 - m_{p_2}) \text{.........} (g).$$

Dr Beddoe has assumed that:

$$m_c = \frac{r_{cp_1} - r_{cp_2} r_{p_1p_2}}{\sqrt{1 - r^2_{p_1p_2}}} \frac{\sigma_c}{\sigma_{p_1}} m_{p_1} + \frac{r_{cp_2} - r_{cp_1} r_{p_1p_2}}{\sqrt{1 - r^2_{p_1p_2}}} \frac{\sigma_c}{\sigma_{p_2}} m_{p_2}.$$

Such a result is contrary to all anthropometric experience*.

There is of course no reason why a formula like (g) should not be tried for skull capacity, but there is only one scientific method of determining it, namely the discovery of the actual means, standard deviations and correlations of the quantities involved for a long series of skulls. We cannot, in the light of modern statistical science, assume:

$$C = A + D_1 p_1 + D_2 p_2,$$

tacitly put $A = 0$, and take a series of guesses at D_1 and D_2, "feeling our way."

But the labour of investigating a formula like (g) is considerable, and no wise person would undertake it without first considering its chances of giving a remunerative result. Let us first enquire into this.

Formula (g) may be written if subscript i stands for I:

$$C = \gamma_0 + (\gamma_1 + \gamma_2 I) p_1,$$

whence:

$$\delta C = (\gamma_1 + \gamma_2 m_i) \delta p_1 + \gamma_2 m_{p_1} \delta I,$$

and ultimately:

$$\sigma_c r_{ci} = (\gamma_1 + \gamma_2 m_i) \sigma_{p_1} r_{p_1 i} + \gamma_2 m_{p_1 i} \sigma_i,$$

$$\sigma_c = (\gamma_1 + \gamma_2 m_i) \sigma_{p_1} r_{cp_1} + \gamma_2 m_{p_1 i} \sigma_i r_{ci}.$$

Eliminating $\gamma_1 + \gamma_2 m_i$ we have:

$$\gamma_2 = -\frac{1}{m_{p_1}} \frac{\sigma_c}{\sigma_i} \frac{r_{p_1 i} - r_{ci} r_{cp_1}}{r_{cp_1} - r_{ci} r_{p_1 i}}.$$

Now we know that r_{ci} is usually very small, and therefore the terms $r_{ci} r_{cp_1}$ and $r_{ci} r_{p_1 i}$ will be small; further, r_{cp_1} is always positive. Hence γ_2 will be of *opposite* sign to $r_{p_1 i}$. Now, so far as we know, nobody has worked out the correlation of p_1 and I, but since the correlation of p_1 and C is positive and large there can be no reasonable doubt that that of p_1 and I will have the same sign as that of C and I. But the correlation of capacity and cephalic index is *negative* for dolichocephalic races and *positive* for brachycephalic races. This conclusion had already been published in a memoir which has been read by Dr Beddoe. We have in fact the following results:

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* See, for example, the multiple regression formulae given for the long bones by K. Pearson, *Phil. Trans.* Vol. 192, A, pp. 186–7, for cranial measurements by A. Lee, *Phil. Trans.* Vol. 196, A, pp. 235–6, and for the like measurements by S. Jacobs, A. Lee, and K. Pearson, *Biometrika*, Vol. II. pp. 349—355. The list might be indefinitely extended.

TABLE II.

Correlation of Capacity and Cephalic Index.

Race	Cephalic Index	Number	Correlation	
♂ Thebans ...	74·8	187	− ·15	− ·15
♂ Naqadas ...	73·2	100	− ·13	
♂ English ...	74·3	77	− ·02*	
♂ Aino	76·5	76	− ·31	
♂ Copts	77·3	56	− ·14	
♂ Etruscans ...	78·5	78	+ ·22	+ ·15
♂ French ...	79·8	56	+ ·14	
♂ Malays ...	81·9	76	+ ·03	
♂ Germans ...	83·3	100	+ ·20	

We see from this table (i) that the relationship between cephalic index and capacity is slight and irregular, and (ii) that any formula like Dr Beddoe's which not only puts γ_0 zero but gives a value to γ_2 persistently constant in magnitude and sign must be erroneous.

(5) Having shewn that Dr Beddoe's correction for cephalic index must be wrong for *individual* crania, when we pass from dolichocephalic to brachycephalic races, because in the former on the average the more dolichocephalic, in the latter the more brachycephalic individuals have the greater capacity, we turn to the main part of his expression (as it appears purely and simply in his first result B_1, in which he takes the capacity solely proportional to the product p_1) and ask whether this is reasonable. A little consideration will show how impossible it is that a formula of the type $C = D_1 p_1$ can at all agree with a formula of the type $C = A + D_1 p_1$ to which the true theory of correlation leads us. In the accompanying figure the two lines are indicated. It will be seen at once that except near the actual mean values of p and C Dr Beddoe's formula cannot possibly give the mean or most probable value of any array. If, however, a small skull be taken with thick walls, or a large skull with thin walls, then Dr Beddoe's formula naturally gives a better result in *extreme* cases. This is the source of any advantage which may appear in its favour when he proceeds to select large crania, "décrits comme minces ou transparents," or small skulls, "décrits comme épais ou lourds," and points out that for certain such cases his rule gives a better result than Dr Lee's correlation formula. This he has actually done in Tables II and III of his paper†. The answer to such criticism is that he has obtained his advantage by causing his line to give bad results for the capacity of the average skull of a given product, i.e. he has swung it round till it makes an angle with the line of "probable values." Thus his guess-work formula is really only a line diverging very considerably from

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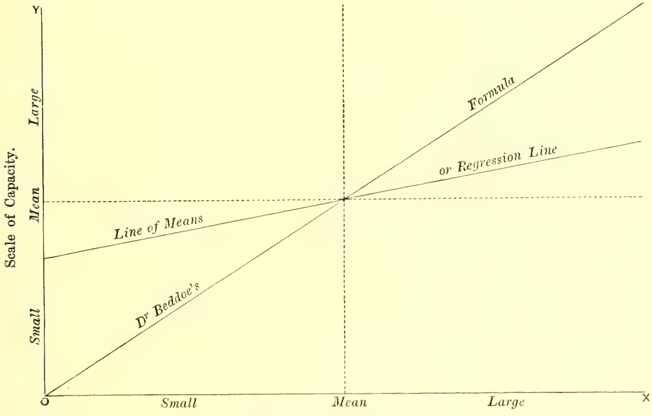
* Deduced from data provided by Dr Macdonell. The result shows that there is sensibly no correlation between cephalic index and capacity in the skulls here dealt with.

† *Loc. cit.* pp. 275 and 276.

the line of most probable values. If he must take a line at all then the only thing open to him is to use the scientific process of correlation and find the best fitting line.



Scale of Product of Arcs.

(6) We now pass to the arcs which Dr Beddoe has chosen for the basis of his formula. We take first his sagittal arc from nasion to inion. Dr Beddoe makes no reference whatever to the difficulty of determining the inion even on the skull. The inion is defined in the *Frankfurter Verständigung* as the point where the *linea superior nuchae* meets the median plane. But since the date of that concordat the further investigation of the matter has shown that this definition is extremely vague. Broca originally defined the inion as the median intersection point of the two *lineae nuchae superiores*. Merkel pointed out that the *protuberantia occipitalis externa* corresponded to the meeting point of two *lineae nuchae supremae*, and termed the meeting point of the *lineae nuchae superiores* the *tuberculum linearum*. Further the inion is often prolonged with a V-shaped projection, and in this case we are told that the median point of the base of this projection is to be considered as the inion, or that the *lineae nuchae* are to be continued on the same *niveau* until a median point is reached, which is to be the inion*. Now we shall term the median point fixed by the *lineae supremae* the *superior inion*, and the point fixed by the *lineae superiores* the *inferior inion*. If these two points coincide, as they may do, then this is the inion proper. Now Schwalbe defines the inion as the common inion of the four *lineae* when they are concurrent, and as the superior inion when they are not. This will work fairly well on many skulls, but our experience shows that on certain skulls, (i) only the inferior inion can be fixed,

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* See especially G. Schwalbe: "Studien über Pithecanthropus erectus," *Zeitschrift für Morphologie und Anthropologie*, Vol. I. p. 24, 1899.

(ii) the two inions can both be fixed, but the inferior may be so far more marked than the superior that without question it would be treated as the inion on the living head, (iii) no inion at all can be determined with any certainty. Testing the living head one may say that if an inion can be fixed, one is not definitely certain whether it is the superior or inferior unless *both* can be determined. That more often than on the skull itself a cautious observer would decline to make any dogmatic statement as to the position of the inion at all. In fact on the skull there is often grave doubt, on the living head there is usually doubt and often gravest doubt as to where the inion should be located; and an occipital *torus* or a bathrocephalic network of ossicles, both not uncommon in English skulls, may completely put out any seeker for the inion on the living head. In short while it is highly undesirable to use the inion instead of the opisthion in any cranial investigation, the introduction of the inion into measurements on the living head is even more to be deprecated.

To illustrate these points we have investigated the inion on an important series (L.S.) of 116 English skulls. There were 50 ♂ and 66 ♀. Among these, owing to defects of one kind or another, 7 ♂ and 6 ♀ had no inion-opisthion distance measurable. The remaining crania we placed before Professor G. Thane and asked him to determine the position of the superior and inferior inions. He most kindly consented to give us all the advantages of his anatomical experience, and we have the following results:

Of the remaining 43 ♂ and 60 ♀ skulls the inion was "unrecognisable" or "undefinable" in 10 ♀ skulls, it was "very doubtful" in 1 ♂ and 2 ♀ skulls, and "vague" in 2 ♂ and 10 ♀ skulls; thus the ♂ skull gives usually a more marked inion than the ♀ skull. The superior inion was determinable more or less accurately in 41 ♂ and 43 ♀, the inferior in 28 ♂ and 23 ♀. In 6 ♀ and 2 ♂ cases the inferior inion *only* was distinguishable; only in 5 ♂ and 3 ♀ the two inions sensibly coincided. On the living head we very much doubt whether any precise inion could have been determined at all in about $\frac{1}{3}$ of the ♀ and $\frac{1}{5}$ to $\frac{1}{6}$ of the ♂ cases. A prominent point would have been taken, but whether it would be the inion at all, and if so whether it was the inferior or superior would not be determinable. The difference between the position of the two inions amounted at a maximum to 11 mm. in the ♂ and 18 mm. in the ♀; the average differences between them being 5 mm. in the ♂ and 8 mm. in the ♀.

The following are the results of measuring the inion-opisthion distance in mms.:

Inion	MALE		FEMALE	
	Mean	Standard Deviation	Mean	Standard Deviation
Superior Inion ...	47·0	4·7	47·2	5·6
Inferior Inion ...	42·3	—	39·2	—

Thus taking the probable error for the inion-opisthion distance in the case of the superior inion we see that half the ♂ population will have inions less than 45 or more than 50 mm., while half the female population will have inions less than 43 or more than 51 mm. from the opisthion. In the face of such a variability what can be said of Dr Beddoe's round 50 mm. for both sexes in his formula B_3 for the inion-opisthion arc? So far as English skulls are concerned he has not got even to the mean value of this arc. We can only protest strongly against a formula which involves such a rough approximation as this being used at all—as Dr Beddoe uses it—when dealing with the skull; it could only be used on the living head supposing there were a complete want of anything better; and this is certainly not the case.

We now turn to Dr Beddoe's transverse circumference, Q' in our notation; we have already seen that it is not the Q of the German or of our measurements, which are taken from the top of one auricular passage to the top of the other. This measurement is made at University College with the skull "horizontal" on the craniophor from the top of one ear-plug to the top of the other. The same point is vital in the consideration of the auricular height. Dr Beddoe without in the least troubling about this point remarks: "Le rayon pariétal de Barnard Davis était je pense identique à la hauteur auriculaire du Dr Lee*." The parietal radius of Barnard Davis differs sensibly from the auricular height of the *Verständigung*, and this error affects all Dr Beddoe's applications of Dr Lee's formulae to Barnard Davis' measurements. We consider that we should be scarcely wrong in allowing even as much as a quarter inch for the difference between the auricular height as measured on a craniophor and Barnard Davis' parietal radius from the centre line of the auricular passages to the *most prominent point of the parietal.*

This is probably the best that can be done, but it only shows how idle it is to attempt to use non-identical systems of measurements in any enquiry of this kind. We may take this opportunity of strongly protesting against the use of Barnard Davis' measurements at all for really scientific work. To begin with his capacities are certainly incorrect. Dr Beddoe reduces them to what he terms Flower's values by subtracting $\frac{1}{20}$, but we have strong reasons for believing that his errors in capacity measurement are not proportional, but to a considerable extent irregular. Further Barnard Davis tabulates his results only to $\frac{1}{10}$ of an inch and this is by no means sufficient for exactitude in craniological investigation. He appears also to have had curious views as to which tenth should be recorded†. In his tables of results for different races he gives in his first column the number of skulls used, but this number does not represent the number used in finding the mean of each character. Hence when the total number is small, as it usually is, no use ought to be made of Barnard Davis' mean results for calculating the mean capacity of the race by a formula. The presence or absence of one or two crania in one or other measurement entirely modifies the values. With our modern results for the continuous variation of skull characters within the race the manner in which Barnard Davis—and he appears to be followed by Dr Beddoe—picks the material upon which the average is to be struck is peculiarly annoying. A brachycephalic skull among a dolichocephalic series of three or four cannot be discarded in striking an average simply because it is brachycephalic! Yet this is the sort of line Barnard Davis adopts, and in very few cases is it possible to determine which skulls he has retained and which he has rejected in striking his average for any given character.

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* *Loc. cit.* p. 271.

† For example, in finding means, where he also stops at the first decimal, he frequently (possibly invariably) records 4·29 as 4·2, and there is no evidence that his individual measurements are not treated in the same way.

(7) From such material as this Dr Beddoe has largely drawn when testing his own formulae against Dr Lee's. He does not give us the information needful to determine whether he has struck fresh averages for himself or used Barnard Davis' averages. If he has used the latter, he seems unaware that he is frequently using means which do not correspond to the skulls used for the mean capacity, and that this is fatal to the validity of his inquiry in short series. In the next place Dr Beddoe has used no consistent or scientific measure of the goodness of the prediction. Generally he has taken the total range of error, which is of course absolutely fallacious. He ought to have used either the mean or mean square error, and to have fixed beforehand what was the standard capacity he proposed to reach. In the next place in using Dr Lee's formulae he has entirely disregarded her instructions as to the manner in which they were to be used. He has applied male formulae to find the capacity of female skulls, although Dr Lee has insisted on the sexual difference. He has used measurements which are not the measurements of her formulae to substitute in them. And lastly, and perhaps of most importance, is the fact that where we can test his arithmetic it is frequently quite incorrect. Surely the time has arrived when we must put aside all personal regard for a veteran and appeal in the interests of science for a totally different treatment and a totally different sense of responsibility when anthropometric problems are discussed.

(8) It is not our purpose in this paper to follow Dr Beddoe page by page and show the fallacy of his conclusions, but it is necessary to illustrate the general character of his methods. The following passage will almost in itself be sufficient:

"Les comparaisons suivantes ont trait à trois crânes de Naqada spécialement cités par Miss Fawcett (p. 20 *op. cit.*[*]).

Manouvrier	B_1	Fawcett	B_3	B_2	P et L	Thompson	Thane
1408	1371	1343	1332	1322	1294	1289	1270

Ici mes procédés nous conduisent à des résultats plus corrects qu'aucun des autres. Je crois que ma méthode est digne d'être placée à côté des autres pour déterminer la capacité cranienne. Je vais maintenant l'appliquer, avec les modifications nécessaires, à la capacité des têtes vivantes[†]."

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[*] The citation is incorrect. It should be *Biometrika*, Vol. I. p. 420.

[†] *Loc. cit.* p. 283.

Now as B_1 and B_2 are formulae destined to give Barnard Davis' capacity and not the true capacity they need not be considered here. What we have to compare are Fawcett's actually measured capacity, Dr Beddoe's B_3 and "*P* et *L*."

Now looking up C. D. Fawcett's paper it will be found that the three skulls referred to have capacities of 1217, 1497 and 1222, which have a mean value of 1312 and *not* 1343 as Dr Beddoe calculates! Further two out of the three skulls are ♀ and Dr Beddoe applies the ♂ formula to them to get his "*P* et *L*" prediction! Lastly Dr Beddoe entirely disregards Dr Lee's instruction to apply the formulae for the most closely allied race, if it be known*. As Dr Lee has provided a formula for Naqada crania, Dr Beddoe ought to have used this; he would then have found for the predicted value of the three crania 1218, 1522 and 1197, giving a mean of 1312, differing by no single point and not by 19 as B_3 does from the observed result. Let us however compare the results for the three crania as found by B_3, not with the special Naqada formulae, but with Dr Lee's general formulae, paying, of course, the proper attention to sex.

TABLE III.

Naqada Skull	Capacity Measured	*P* and *L* Predicted		B_3 Predicted
		Naqada	General	
1308 ♀ *B* 24^b ♂ *B* 21 ♀	1217 1497 1222	1218 (− 1) 1522 (−25) 1197 (+25)	1195 (−22) 1507 (+10) 1175 (−47)	1154 (− 63) 1602 (+105) 1182 (− 40)
Mean ... Mean Error	1312 —	1312 (0) 17	1292 (−21) 26	1313 (+1) 69

Now supposing we have followed Dr Beddoe correctly his results were not only 30 cubic centimetres wrong in taking the average of Miss Fawcett's three skulls, but 19 cubic centimetres wrong in using his own formula! This brings his predicted mean into close accord with Miss Fawcett's observed mean result. But we see at once on examining the three individual predictions that his success is only achieved by the balancing of large individual errors. His mean error is four times as bad as the *P* and *L* Naqada prediction and nearly three times as bad as the *P* and *L* general formula prediction. Allowing for faults of arithmetic, results similar to these must have been actually before Dr Beddoe when he wrote:

"Mes procédés nous conduisent à des résultats plus corrects qu'aucun des autres," etc.

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* The University College anthropometric workers have again and again insisted that regression formulae vary from race to race. See *Phil. Trans.* Vol. 196, A, pp. 243 *et seq.*; *Biometrika*, Vol. I. pp. 460–1; Vol. II. pp. 347 *et seq.*

Hence as he certainly would not have screened them behind a mean value, we are forced to the conclusion that he really did not grasp their significance, or in other words that he is quite unfitted to deal with such statistical enquiries. But Dr Beddoe's agreement in the matter of the mean of the three skulls when his arithmetic is corrected is not only fallacious because it depends upon large individual errors of opposite sign but because he has used the *wrong values* of the auricular circumferences. To obtain his Q' he ought to have added at least 10 mm. to Miss Fawcett's Q. If this be done, his values for the three capacities are 1195, 1613 and 1232 respectively, giving a mean of 1347 and a mean error of 49,—results markedly worse than P and L. We do not know whether Dr Beddoe would prefer to somewhat reduce his mean error at the expense of his mean, or to get a good mean with an excessive mean error. As he uses our Q for his own transverse circumference, we must suppose the latter to be the case and shall not attempt to modify this arc for the remainder of this paper when applying his B_3.

In concluding this section we may note the results obtained by using our new circumferential formulae. We have applied the English ♀ formula* to the female skulls and the mean ♂ formula and the Naqada ♂ formula to the male skull. The following are the results:

TABLE IV.

Naqada Skull	Capacity Measured	Mean ♂ and English ♀	Naqada ♂, English ♀
1308 ♀	1217	1203 (−14)	1203 (−14)
B 24^b ♂	1497	1542 (+45)	1527 (+30)
B 21 ♀	1222	1230 (+ 8)	1230 (+ 8)
Mean ...	1312	1325 (+13)	1320 (+ 8)
Mean Error	—	22	17

Thus the method of correlation, whether we use diameters or circumferences, gives for these three skulls immeasurably better results than Dr Beddoe's B_3; yet it is as a corollary to his results for these three crania that he writes:

"Je crois que ma méthode est digne d'être placée à côté des autres pour déterminer la capacité cranienne."

(9) We have already given our reasons for dissenting from Dr Beddoe's methods of applying his own and the University College workers' formulae to his material, and also our objections to the use of Barnard Davis' material at all†. Still this material, allowing for the rough approximations which have to be made

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* The only series for which the female data has so far been reduced.

† It is greatly to be desired that a complete system of modern measurements should be taken and published, not only on the Barnard Davis collection, but on the remainder of the splendid material in the possession of the Royal College of Surgeons.

to apply the formulae to it, shows in a sufficiently marked manner the superiority of the correlation formulae over Dr Beddoe's purely empirical guess-work. We propose to test this on two of Barnard Davis' series. We will first take a series of nine groups of skulls and predict their means by B_3, P and L, and $G.F.$, where $G.F.$ stands for the general male formula (f) for circumferences given on p. 371 of this paper. In order to apply our results we have not taken Barnard Davis' mean values, which we have seen are unreliable, but have worked out afresh the means for all the ♂ crania in each series for which the entire system of characters needed are given. These characters are (i) the capacity C, (ii) the maximum length L, (iii) the maximum breadth B, (iv) the auricular height H, (v) the cephalic index I, (vi) the horizontal circumference U, (vii) the sagittal circumference S, (viii) the transverse circumference Q. We have obtained Dr Beddoe's S' from S by deducting, as he asserts, 1·97 inches for the inion-opisthion arc, and his Q' from the intermastoid arc of Barnard Davis by subtracting 2·3 inches, as he does. We reach our auricular height from Barnard Davis' parietal radius by subtracting ·25 inches, and our Q from his intermastoid arc by subtracting 2·5 inches. Only in the case of the Thais which number only four crania have we calculated the capacity of each individual skull and taken the mean result; in all the other cases the formulae had been used on the mean values of the characters. The measurements are in inches except C and I.

TABLE V.

Mean Values of Characters in 9 Races. ♂ Crania.

Race	No.	C in ozs.	L	B	H	I	U	S	Q
Romans of Britain	8	73·3	7·3	5·7	4·4	77	21·0	14·8	12·1
Australians ...	16	67·6	7·3	5·3	4·3	72	20·3	14·7	11·6
New Hebridians...	9	72·1	7·1	5·1	4·5	73	20·0	14·8	11·8
Kanakas ...	66	77·2	7·0	5·6	4·8	79	20·3	14·9	12·8
Marquesans ...	17	78·9	7·1	5·6	4·7	78	20·5	14·8	12·5
Netherlanders ...	16	79·5	7·2	5·7	4·5	79	20·7	14·7	12·5
Finns	7	79·2	7·0	5·8	4·6	82	20·6	14·8	12·7
Russians	11	80·9	7·4	5·8	4·5	78	21·2	15·0	12·4
Thais 1	1	76·0	6·6	5·6	4·85	84	19·8	14·6	13·3
„ 2	1	81·0	7·4	5·4	4·75	73	20·5	15·3	12·6
„ 3	1	79·0	6·6	5·9	4·75	89	20·2	14·3	13·4
„ 4	1	78·0	6·8	5·5	4·75	80	19·7	14·9	12·5

Dr Beddoe's S' and Q' are to be found from the above tabled values by subtracting 2 inches* from S and adding ·2 inches to Q respectively. The reader may well ask what is the value of such an attempt to reach indirectly quantities directly measurable on the skull? We should reply: Probably no value at all! We have seen that the inion-opisthion arc is extremely variable and the same statement must be made with regard to the size of the mastoid processes. To assert that the mean value of the difference between the intermastoid arc and the bi-auricular arc is 2·3 inches is in our opinion wild guesswork, and even if it were true it neglects entirely the immense variability of this difference. We cannot expect any formula to give good results under such treatment, but as Dr Beddoe has chosen such a test we consent to accept it, especially as it enables us to indicate to the craniological reader the sort of statistico-metrical treatment which seems to have passed hitherto as science. In the following table we give first the supposed measured value of the capacity, i.e. Barnard Davis' values less 1/20 and reduced to cm.^{3}; then we give the predicted values and differences of B_3, P and L, and $G. F.$, and finally the mean errors of the three formulae.

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* 50 mm. = 1″·97, but as Davis' values are given to $\frac{1}{10}$ inch only the $\frac{7}{100}$ cannot be considered.

TABLE VI.

Comparison of Cranial Formulae on Barnard Davis' Measurement of Mean Racial Capacity.

Race	Capacity	B_3	Δ	P and L	Δ	$G. F.$	Δ
Romans of Britain...	1385	1490	+105	1431	+46	1463	+78
Australians ...	1277	1347	+ 70	1330	+53	1366	+89
New Hebridians ...	1362	1366	+ 4	1309	−53	1376	+14
Kanakas	1459	1544	+ 85	1462	+ 3	1499	+40
Marquesans ...	1491	1507	+ 16	1454	−37	1473	−18
Netherlanders ...	1502	1515	+ 13	1441	−61	1477	−25
Finns	1497	1559	+ 62	1454	−43	1499	+ 2
Russians	1529	1570	+ 41	1492	−37	1522	− 7
Thais	1483	1539	+ 56	1430	−53	1487	+ 4
Mean	1443	1493	+ 50	1416	−27	1462	+19
Mean Error ...	—	—	50	—	43	—	31

In deducing the results P and L we have, owing to the mixture of races involved, used Dr Lee's most appropriate formula (10) *bis*, that in the footnote on p. 247 of her memoir*, based on the best results for the *means* of 10 races. It will be seen at once that P and L and $G. F.$ present much better results than B_3 which is far worse than either in determining the mean value of the whole series, and is worse than our formula by at least 50 per cent. in the mean error.

If Dr Beddoe considers that his formula has given all plus errors and therefore can be approximately bettered by reduction in his multiplier, we must call his attention to the following table, which is a reconstruction* of his Table III for the eight skulls out of his ten, for which we could find the requisite data:

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* *Phil. Trans.* Vol. 196, A, p. 247. We have used this formula throughout for race means because it is based on racial *means* and not on individual skulls. Experience has shown that in the long run it works better than (10). The latter is much better for this series, giving a mean value 1446, only three in excess, and a mean error of only 35! We have not, however, taken advantage of this superiority to use it.

TABLE VII.

Race	Capacity	B_3	Δ	*G. F.*	Δ
♂ Mountain Chinese .	1473	1423	− 50	1407	− 66
♀ Cossack	1530	1406	−124	1371	−159
♀ Hindu	1133	1050	− 83	1115	− 18
♂ Fatuhivan... ...	1720	1700	− 20	1538	−182
♀ Bodo	1644	1443	−201	1394	−250
♂ Australian ...	1313	1243	− 70	1292	− 21
♀ Papuan	1313	1228	− 85	1263	− 50
♂ Dutchman... ...	1644	1613	− 31	1543	−101
Mean Error ...	—	—	− 83	—	−106

Now B_3 is certainly better here than *G. F.* and the answer is perfectly simple if the reader will turn to the diagram on p. 375. For small skulls with more than the average capacity our result must be too small, but better than Dr Beddoe's; for large skulls with more than the average capacity Dr Beddoe's will give a better result than the line of mean values. In the above table Dr Beddoe has only taken three small skulls with more than the average capacity and we are naturally in all those cases better than he is. In the other cases of big skulls he is better than we are, and roughly better as the skulls are bigger. If he had only had a majority of small skulls with big capacities the tables would have been turned upon him. The fact is that nothing can be determined at all by Dr Beddoe's Tables II and III for 'thick' and 'thin' crania; by judicious selection of small thin skulls and big thick skulls we can make B_3 give execrable results as compared to *G. F.* or P and L, the selection being made before the predictions have been calculated. It all depends upon looking at the diagram on p. 375 and choosing skulls which fall on the other side of the Beddoe line to the regression line. What is quite clear from B_3 in Table VII is that Dr Beddoe cannot improve the results given in Table VI without making his position in Table VII much worse; i.e. he must sacrifice his claim to be better than us on *selected* individual crania. For whereas B_3 gives far too big values on Table VI, it gives far too small values on Table VII. To really test the correlation formulae against the guesswork formula of Dr Beddoe, the individual skulls must be sampled *at random* and not *selected.* To do this we started at p. 20 of Barnard Davis' *Thesaurus* and extracted the first male *undeformed* skull with the necessary data on this page, or if there happened to be none on this page, the nearest male skull on the preceding page or pages. We then passed to pp. 35, 40, 55, etc. in order, repeating the process until 20 skulls had been extracted and the following table resulted. To this we applied P and L*, $G. F.$ and B_3, with the results in Table IX.

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* Dr Beddoe's Table exhibits a number of misprints or arithmetical slips, and is invalid as far as P and L is concerned, because he has used male formula for female crania, and an erroneous value for the auricular height.

TABLE VIII.

Individual Crania Sampled at Random from Barnard Davis.

Race	Barnard Davis' Number	C†	L	B	H	I	U	S	Q	S'	Q'
(1) Ancient Roman ...	171 (p. 18)	70·0	7·2	5·6	4·25	76	20·7	14·5	11·7	12·5	11·9
(2) Anglo-Saxon ...	674 (p. 34)	75·0	7·4	5·5	4·75	74	20·8	14·5	12·4	12·5	12·6
(3) English	1029 (p. 48)	94·0	8·0	6·3	5·25	78	22·8	16·6	14·4	14·6	14·6
(4) Scottish Highlander	176* (p. 64)	71·0	6·8	5·5	4·25	80	19·7	13·7	11·8	11·7	12·0
(5) French	1312 (p. 80)	74·5	6·9	5·4	4·25	78	20·0	14·1	11·6	12·1	11·8
(6) Italian	1178 (p. 95)	73·0	7·1	5·2	4·35	73	20·2	14·6	11·7	12·6	11·9
(7) Dutch Jew ...	1328 (p. 110)	79·5	7·5	5·5	4·35	73	21·2	15·0	12·0	13·0	12·2
(8) Russian Tartar ...	941 (p. 125)	76·5	7·0	5·7	4·45	81	20·6	14·6	12·0	12·6	12·2
(9) Hindoo	487 (p. 140)	69·0	6·8	5·5	4·55	80	19·5	14·3	12·3	12·3	12·5
(10) Gond	808 (p. 155)	65·5	6·8	4·9	4·45	72	18·8	14·1	11·7	12·1	11·9
(11) Bodo	735 (p. 169)	68·0	6·8	5·5	4·55	80	19·6	14·2	12·5	12·2	12·7
(12) Egyptian Arab ...	1015 (p. 185)	67·0	7·1	5·4	4·55	76	20·1	14·4	12·0	12·4	12·2
(13) Fantu	262 (p. 200)	67·0	6·9	5·2	4·55	75	19·3	14·4	12·1	12·4	12·3
(14) Kafir	586 (p. 215)	64·0	7·4	4·9	4·35	66	20·2	14·6	11·4	12·6	11·6
(15) Vancouver Islander	1211 (p. 229)	85·0	7·5	5·7	4·65	76	21·0	15·4	12·7	13·4	12·9
(16) Aymara	1198 (p. 244)	82·0	7·1	5·6	4·75	79	20·5	14·8	12·6	12·8	12·8
(17) Australian ...	99 (p. 260)	69·0	7·0	5·6	4·35	80	20·0	14·3	12·0	12·3	12·2
(18) Sumatran	1367 (p. 275)	67·0	7·0	5·1	4·35	72	19·8	14·0	11·4	12·0	11·6
(19) Dyak	280 (p. 290)	60·0	6·6	4·9	4·65	74	18·7	13·7	10·7	11·7	10·9
(20) Papuan	1401 (p. 305)	73·0	6·5	5·4	4·45	83	19·4	13·5	12·0	11·5	12·2

Here again we reach the same general conclusions, namely the correlation formulae give not only better means for the whole series, but less mean errors, and this, although a whole series of assumptions has to be made to get any results from them at all, if Barnard Davis' material be used. The further point has to be borne in mind that B_3 was 'guessed' to fit Barnard Davis' material, whereas the correlation formulae were calculated from data measured in an entirely different, and we consider, in a far more correct manner‡. Any mathematician using a formula of Dr Beddoe's type could get immeasurably better results by least squares or by correlation from Barnard Davis' data, but the labour would be wasted, for the formula would only apply to the very doubtful measurements of the *Thesaurus Craniorum* and not to the more reliable measurements now made in both Germany and England.

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* If L, B, H be measured in inches the formula to give C in cubic centimetres is nearly for males: $C = 406{\cdot}01 + 5{\cdot}52214\, L \times B \times H$. This is the mean formula of Dr Lee for finding the capacity of *individual* crania.

† Ozs. of Calais sand. To be multiplied by Topinard's factor 19·89 to reduce to cubic centimetres and then by 19/20 to reduce to cranial capacities as now measured. The other measurements are in English inches.

‡ We believe the rise in the mean error from 47 to 64 when we pass from suitably measured crania (p. 371) to Barnard Davis' material is almost entirely due to the vagueness of the allowances to be made and the crudeness of Barnard Davis' measurements.

TABLE IX.

Table of Capacities of 20 Individual Crania Sampled at Random from Barnard Davis.

Individual	Capacity	B_3	Δ	P & L	Δ	$G. F.$	Δ
(1) Ancient Roman ...	1323	1383	+ 60	1352	+ 29	1383	+ 60
(2) Anglo-Saxon ...	1417	1461	+ 44	1474	+ 57	1457	+ 40
(3) English	1776	2197	+421	1867	+ 91	2011	+235
(4) Scottish Highlander	1342	1259	− 83	1284	− 58	1276	− 66
(5) French	1408	1291	−117	1280	−128	1305	−103
(6) Italian	1379	1347	− 32	1293	− 86	1362	− 17
(7) Dutch Jew ...	1502	1494	− 8	1397	−105	1481	− 21
(8) Russian Tartar ...	1446	1446	0	1386	− 60	1414	− 32
(9) Hindoo	1304	1365	+ 61	1346	+ 42	1356	+ 52
(10) Gond	1238	1199	− 39	1225	− 13	1249	+ 11
(11) Bodo	1285	1382	+ 97	1346	+ 61	1372	+ 87
(12) Egyptian Arab ...	1266	1366	+100	1369	+103	1370	+104
(13) Fantu	1266	1318	+ 52	1308	+ 42	1325	+ 59
(14) Kafir	1209	1281	+ 72	1277	+ 68	1334	+125
(15) Vancouver Islander	1606	1630	+ 24	1504	−102	1575	− 31
(16) Aymara	1549	1524	− 25	1449	−100	1483	− 66
(17) Australian ...	1303	1366	+ 63	1348	+ 45	1356	+ 53
(18) Sumatran	1266	1222	− 44	1264	− 2	1268	+ 2
(19) Dyak	1133	1063	− 70	1236	+103	1133	0
(20) Papuan	1379	1251	−128	1269	−110	1263	−116
Mean	1370	1392	+ 22	1364	− 6	1389	+ 19
Mean Error ...	—	—	77	—	70	—	64

(10) We next turn to measurements made on crania on the basis of the Frankfurt *Verständigung*, for which our formulae have been calculated. Here our difficulty lies with deducing Dr Beddoe's values, but as he expresses satisfaction with the fit of his formula for the Naqada skulls, using our Q, we will continue to use that quantity for his auricular arc Q'. We do not suppose any correction

TABLE X.

Races Measured according to Frankfurt Verständigung.

Race (♂s)	C	L	B	H	I	U	S	Q	S'
Altbaierisch (78)	1503	180·6	150·5	120·7	83·3	524·3	365·1	329·7	315·1
English (72) ...	1477	189·1	140·7	114·6	74·4	524·3	377·1	307·9	327·1
French (56) ...	1473	180·0	143·4	112·9	79·8	518·2	366·0	312·2	316·0
Aino (76) ...	1462	185·8	141·2	119·3	76·5	522·5	372·8	328·5	322·8
Etruscan (78) ...	1454	182·9	143·5	115·9	78·5	522·8	376·0	317·0	326·0
Malay (39) ...	1424	174·3	142·4	116·9	81·9	505·2	365·3	320·8	315·3
Theban (164) ...	1388	181·9	136·6	114·3	74·8	510·8	372·4	306·1	322·4
Naqada (98) ...	1381	185·1	134·9	115·6	73·0	511·0	373·0	304·2	323·0
Copt (59) ...	1356	179·1	136·5	115·4	77·3	501·8	365·9	311·8	315·9
Negro (39) ...	1348	182·8	133·2	115·0	72·9	508·5	367·7	306·8	317·7

would be really satisfactory, and least of all to him. We use, as before, Dr Lee's inter-racial formula from the footnote, p. 247 of her memoir, i.e.

$$C = 321{\cdot}16 + {\cdot}000{,}370 L \times B \times H.$$

The following results were obtained by using the three prediction formulae.

TABLE XI.

Predicted Capacities of 10 *Races.*

Race	C	B_3	Δ	P and L	Δ	$G.\ F.$	Δ
Altbaierisch ...	1503	1530	+27	1535	+32	1493	−10
English ...	1477	1439	−38	1449	−28	1448	−29
French ...	1473	1419	−54	1399	−74	1415	−58
Aino	1462	1521	+59	1479	+17	1509	+47
Etruscan ...	1454	1494	+40	1444	−10	1477	+23
Malay	1424	1428	+ 4	1395	−29	1415	− 9
Theban ...	1388	1376	−12	1372	−16	1397	+ 9
Naqada ...	1381	1362	−19	1389	+ 8	1396	+15
Copt	1356	1361	+ 5	1366	+10	1377	+21
Negro	1348	1344	− 4	1357	+ 9	1379	+31
Mean ...	1427	1427	0	1419	−8	1431	+4
Mean Error ...	—	—	27·2	—	23·3	—	25·2

Again both the correlation formulae come out with a less mean error than Dr Beddoe's B_3, the diametral formula being sensibly the best. For the means Dr Beddoe is slightly better. We may stay here to note that *G. F.* is really a mean individual and not an inter-racial formula. The inter-racial formula for these ten races gives us:

$$C = 316{\cdot}2 + {\cdot}01852\, U \times S \times Q.$$

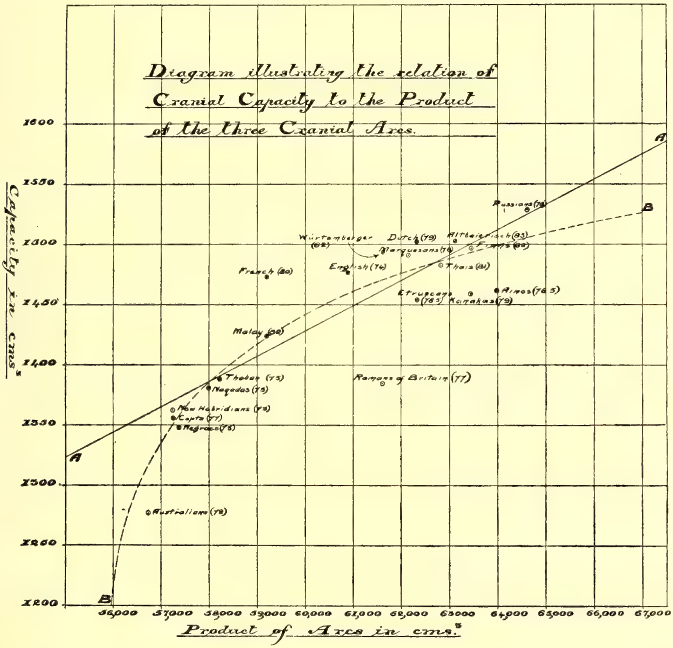
This formula should be used in preference to *G. F.* for race means. It does not however give any very substantial advantage in the present case.

We have for the inter-racial arc formula (*I. A. F.*)

TABLE XII.

Race	Observed	$I.\ A.\ F.$	Δ	Race	Observed	$I.\ A.\ F.$	Δ
Altbaierisch .	1503	1485	−18	Theban ...	1388	1394	+ 6
English ...	1477	1444	−33	Naqada ...	1381	1390	+ 9
French ...	1473	1413	−60	Copt ...	1356	1377	+21
Aino ...	1462	1501	+39	Negro ...	1348	1379	+31
Etruscan ...	1454	1476	+22				
Malay ...	1424	1413	−11	Mean ...	1427	1427	0
				Mean Error	—	—	25·0

We have in this formula the mean value equal to that of the observed races, but the mean error is only reduced ·2, in other words our *G. F.* is not substantially bettered, it is as good a fit as can be got for this series from a *linear* formula. But this best fitting line is interesting from another point of view, which is exhibited in the accompanying diagram. We have plotted here the observed capacities of 19 races, the above 10 races and the 9 doubtfully measured races from Barnard Davis; the horizontal abscissa is the product in cubic centimetres of the three arcs *U*, *S* and *Q*. We have added the cephalic indices. The straight line *AA* is the inter-racial regression line based on the 10 races. We see that with the



exceptions of the Malays and the Marquesans*, both fairly close to the inter-racial line *AA*, all the other races above the line are *modern Europeans*. In other words it would appear that the modern European races gain their advantage in skull capacity over the lower or more primitive races largely by thinner bone. Of the races above the best fitting line Dutch, English, Russians, Marquesans, will have their values as calculated altered *for the worse* by Dr Beddoe's correction for cephalic index, the French will remain unaltered (although they want most correction!) and the Altbaierisch and Malay will be slightly improved (although they stand least in need of correction!). Of the races below the line all but Finns would be improved by correction although in several cases they would be over corrected. But a very slight inspection shows that the corrections needed are in no way proportional to the defect of their cephalic indices from 80. Thus omitting Australians, the Ainos, Kanakas, Etruscans and Romans of Britain* (all over 75) want most correction; while Thebans, Naqadas, New Hebridians (all under 75) want far less correction. In fact we consider that if Dr Beddoe had formed a similar diagram he would not have laid any stress on his cephalic index correction. What does seem to us to follow from this diagram is the non-linearity of the inter-racial regression line. It is very markedly curved. We have therefore endeavoured to correct by aid of a curved line. Until more data are available, measured and reduced in a uniform manner, it is not worth spending much labour in calculating the constants of possible formulae, but we may roughly point out how we get far better results by correcting for non-linearity of the regression curve for inter-racial results than by attempting to "compensate" by cephalic index. Two hypotheses occurred to us, (i) the regression line instead of being $C = a_1 + A_2P$, where P is the product $U \times S \times Q$, may be taken

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* "Without exception the finest race of people in this sea. For fine shape and regular features they perhaps surpass all other nations." Cook, *Voyage towards the South Pole*, 1777, Vol. I. p. 308.

$$C = a_1 + A_2P + a_3P^2$$

or as parabolic, (ii) the regression line may be taken as logarithmic

$$P + a_4 = a_5e^{a_6C}.$$

The only reason, and it is very slight, for the latter form is that it makes the increment of C not only directly proportional to the increment of P, but inversely proportional to the absolute magnitude of P measured from a certain value. A very similar curve has been found to suit the change in human physical measurements with age. The curve is here used merely as a form judged likely from the observations, and without at present any statement of a theoretical basis being suggested. We have found roughly the constants from the 10 races available. There result the two formulae, P being in cubic centimetres:

$$\begin{aligned} C &= -15319{\cdot}6 + {\cdot}531{,}942P \qquad - 4{\cdot}2075P^2/10^6 \\ C &= 704{\cdot}04 \qquad + 203{\cdot}05 \log_{10}(P - 55682). \end{aligned}$$

The disadvantage of the first formula is that with the constants selected, one reaches a value of P after which the capacity begins to decrease, but a very little change of the constants would suffice to throw this value up to, say 1550 cms.^{3}, a value exceeding any *racial* mean† hitherto observed. The logarithmic formula we consider preferable as it suffers from no such defect. Table XIII gives the results, compared with Dr Beddoe's compensation formula. We see at once that either of our formulae based on the obvious fact of non-linearity is far superior to his B_3, not only in the mean of each series, but in the mean error. In fact in only two cases out of the 19 races is he better than the parabolic and in only three cases better than the logarithmic formula. Thus in his Barnard Davis results he is nearly 100 per cent. worse than the logarithmic formula. Nor can he better himself by changing his multiplier because he has already got a zero deviation from the mean of his series in the *Verständigung* measurements, i.e. the far better series. So soon as material is reduced on a uniform basis for inter-racial data, we believe it will be possible to adjust the constants of a non-linear inter-racial regression formula to read with a mean error of under 14 cms.[3]. We do not attempt this at present, because the bulk of sound material is insufficient.

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* We are inclined to doubt entirely the *data* for the Romans in Britain. It differs so widely from Romans elsewhere. We hope that these skulls may be remeasured shortly.

† We ask the reader to particularly note the words "*racial* mean," for our formulae are not to be transferred without further consideration to the calculation of individual capacities (or indeed to the female sex).

TABLE XIII.

Race	$U \times S \times Q$	Capacity	B_3	Δ	Parabolic Formula	Δ	Logarithmic Formula	Δ
Altbaierisch ...	63118	1503	1530	+ 27	1493	−10	1490	−13
English	60878	1477	1439	− 38	1470	− 7	1459	−18
French	59206	1473	1419	− 54	1428	−45	1424	−49
Aino	63988	1462	1521	+ 59	1491	+29	1500	+38
Etruscan ...	62327	1454	1494	+ 40	1490	+36	1480	+26
Malay	59197	1424	1428	+ 4	1425	+ 1	1424	0
Theban	58223	1388	1376	− 12	1389	+ 1	1395	+ 7
Naqada	57991	1381	1362	− 19	1379	− 2	1387	+ 6
Copt	57254	1356	1361	+ 5	1344	−12	1353	− 3
Negro	57373	1348	1344	− 4	1350	+ 2	1359	+13
Mean	59955·5	1427	1427	0	1426	− 1	1427	0
Mean Error ...	—	—	—	27·2	—	14·5	—	17·3
Romans in Britain	61609	1385	1490	+105	1482	+97	1470	+85
Australians ...	56722	1277	1347	+ 70	1316	+39	1317	+40
New Hebridians	57234	1362	1366	+ 4	1343	−19	1352	−10
Kanakas	63441	1459	1544	+ 85	1493	+34	1494	+35
Marquesans ...	62145	1491	1507	+ 16	1489	− 2	1478	−13
Dutch	62327	1502	1515	+ 13	1490	−12	1480	−22
Finns	63447	1497	1559	+ 62	1493	− 4	1494	− 3
Russians ...	64614	1529	1570	+ 41	1485	−44	1506	−23
Thais	62827	1483	1539	+ 56	1493	+10	1487	+ 4
Mean	61596	1443	1493	+ 50	1454	+11	1453	+10
Mean Error ...	—	—	—	50	—	29	—	26
Mean of 19 Races	60733	1434	1458	+ 24	1439	+ 5	1439	+ 5
Mean Error ...	—	—	—	38	—	21	—	21

(11) We now turn to our last test, that on individual crania measured on the basis of the Frankfurt Concordat. We have taken 45 ♂ skulls by sampling at

random[*] C. Fawcett's Naqada, T. Ranke's 'Altbaierisch' and E. Schmidt's Theban mummy measurements. We have applied Dr Lee's mean formula for individual crania[†]. B_3 and the general formula were used as in the series of Table XI. It is impossible to print all the measurements and results for these 45 skulls but the general conclusions are given in the table below:

TABLE XIV.

Results of the Three Formulae for 45 ♂ *Crania.*

Series	Quantity	B_3	P and L	$G. F.$
Naqada Series ...	Mean Error	64	50	51
Altbaierisch Series ...	Mean Error	50	62	49
Theban Series ...	Mean Error	49	46	42
Whole Series	Mean Error Range of Error	54 +245 to − 169	53 +141 to − 164	47 +148 to − 165

For a brachycephalic race as we see from the table Dr Beddoe gains by his cephalic index correction and this is the source of his advantage over P and L for the Altbaierisch. But for a dolichocephalic race like the Naqada or Theban he loses; thus his biggest negative error arises in the case of the largest Naqada skull where his correction for cephalic index still further reduces his underestimate.

On the whole again we see that the advantage lies with the correlation formulae. Summing up our results we should say that for the skull:

(i) Intra-racial and inter-racial formulae can be found for circumferential measurements which are superior, or at any rate equal to Dr Lee's diametral formulae.

(ii) Such formulae give better results when their constants are found by statistical theory than by mere guesswork.

(iii) The vagueness of the inion as a point of measurement renders it of the greatest importance that the sagittal arc should be measured from the opisthion and not from the inion.

(iv) It is conceivable that a double regression formula would work better than a single regression formula like P and L or our present $G. F.$ But it will hardly be obtained by taking as the second variable the product $I \times U \times Q \times S$.

(v) Probably the best inter-racial results will be obtained by non-linear regression formulae based on a single product.

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[*] For the mummies every tenth skull starting with No. 489 of the Catalogue was taken; for the Naqada every tenth skull so far as possible, allowing for the mixture of ♂ and ♀ on the list; for the Altbaierisch,' every fifth as far as the requisite data were provided.

[†] $C = \cdot 000337\, L \times B \times H + 406 \cdot 01$.

We hope later to publish double regression formulae for skull capacity, but if it is to be done by the use of an index, we do not believe that the cephalic index is the right character to use, because it has been shown to have small correlation with the capacity, and what correlation does exist changes sign from race to race. On the whole we believe that increased accuracy is to be sought as we have indicated on p. 388* by using non-linear regression rather than multiple regression formulae, unless indeed one variable of the latter be the thickness or the weight of the skull.

(12) Having dealt with the application of Dr Beddoe's formula to skulls, we now turn to its *raison d'être*, i.e. its applicability to the living head. We have already considered one grave objection, namely, that the inion is on the skull itself by no means a definite and easily located point. On the living head we find it even more difficult to determine it with certainty. By throwing the head forward in *certain* cases the boundary of the area to which the muscles are attached can be appreciated, but "well-marked inions," i.e. large bony growths in the neighbourhood of the inion, occipital ridges and toruses, especially frequent in English heads, render the exact localisation extremely problematical. Let us suppose, however, that the inion could be ascertained on the living head, then the measurement of the three arcs seems to us entirely valueless on account of the varying amount of hair. Dr Beddoe really makes no attempt to meet Topinard's objection to the use of these arcs on the living head, except by the remark that abundance and stiffness of hair is not usually met with in combination with intellectual eminence! He gives no statistics, however, of the relative baldness of the average middle-aged agriculturist, tradesman, or man of science. Without such statistics his remark is worthless. Having a bad case himself he simply drops it in order to point out the difficulties of rival formulae! Thus he writes†:

> Cette objection en ce qui concerne les cheveux s'applique aussi à la hauteur auriculaire et au maximum de longueur et largeur, lorsqu'ils sont pris au céphalomètre et non avec le compas d'épaisseur.

We do not know to what form of cephalometer Dr Beddoe is referring, but any anthropologist would be perfectly incompetent for his task who could not devise an instrument for reading the auricular height by a sufficiently blunt point so that the determination of the height would not be affected sensibly by the existence of the hair. You can clear the hair to one side when measuring the diameters, you cannot possibly get it out of the way when using the measuring tape. This is not mere theoretical reasoning, but the actual result of experience in practice. Next Dr Beddoe endeavours to discredit the allowance Dr Lee has made for the thickness of the flesh on the living head. It seems to have escaped him that if the varying thickness of the flesh is a real difficulty in determining the diameters, its effect on his own arcs (in addition to the effect of the hair!) can hardly be described as less than insuperable. But we are not inclined to give much weight to his objection. Comparing the mean diameters found from more than 100 English ♂ skulls with the means found on more than the same number of living ♂ heads we have differences of 9, 12, and 11 mm. in the case of maximum length, breadth and auricular height respectively. Dr Lee's allowance of 11 cms. seems therefore a very reasonable one, and is closer than it appears, for the heads were certainly—allowing for the difference of skull and head—more brachycephalic than the earlier skulls. We do not say that Dr Lee's method is beyond criticism; on the contrary we recognise all the inherent difficulties of the problem. But we believe these difficulties to be enormously exaggerated by Dr Beddoe, and that he screens behind this exaggeration the far greater difficulties associated with his own method of arc measurement.

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* *Phil. Trans.* Vol. 192, A, pp. 222 *et seq.*

† *Loc. cit.* p. 285.

(13) As to his application of that method to demonstrate the correlation of intelligence and skull capacity, we hold it to be quite fallacious. To begin with he selects a formula—by guesswork—which is theoretically incorrect. He drops his formula for the skull and takes the product of $\frac{1}{3}$ of each of his arcs, and divides this product by 2000. He then increases it by $\frac{1}{3}$ per cent. for every unit of the cephalic index above 50. In his cranial formula he made no correction for cephalic index when it was 80. He now drops the neutral index to 50 without any justification or explanation. As we have already seen that the correlation between cephalic index and the capacity of the English skull is *negative*, his formula will tend to exaggerate the capacity of the brachycephalic and lower the capacity of the dolichocephalic individual heads. Now we believe it to be a fact—whatever may be the explanation, lie it in environment, nurture or difference of race—that the well-to-do classes in this country are now more round-headed than the working classes*, but such are the classes which produce the bulk of the people who work intellectually, and therefore Dr Beddoe's erroneous allowance for brachycephaly directly tends to emphasise the cranial capacity of the intellectual classes.

Dr Beddoe says that according to Dr Lee there is no correlation between the development of the intelligence and the cranial capacity, and remarks†:

> Les matériaux sur lesquels cette dernière opinion est basée sont rares et peu concluants.

Dr Lee makes no such statement at all. What she asserts is‡:

"That there is *no marked* correlation between skull capacity and intellectual power."

Dr Beddoe forgets to draw attention to the fact that Dr Lee, in conjunction with ourselves, has actually measured the relation between size of head and intelligence, and on far more ample material than Dr Beddoe uses. We find the correlation sensible, but so small that it is impossible to base any prediction from the size of head as to general intelligence§. As to Dr Beddoe's own data bearing on intelligence and capacity, we can only repeat Dr Lee's words, which he would have done well to take to heart, namely that to solve a problem of this kind it is absolutely needful to keep within one "fairly equally nourished class," and if possible within one local race. We do not minimise the difficulty of doing this, but until it is done no final answer can be given to the problem. Much of the discussion at present might be summed up in such an absurd argument as: The Bavarians have as a race a larger skull capacity than the French; they are a less keen-witted race; ergo: smaller skull capacity goes with intelligence. We take it such an argument would be quite as valid as Dr Beddoe's comparison of Highlanders and East Anglians, or of Cornishmen of the upper and lower classes.

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* See *inter alia* Macdonell, *Biometrika*, Vol. I. p. 190.

† *Loc. cit.* p. 267.

‡ *Phil. Trans.* Vol. 196, A, p. 259.

§ *R. S. Proc.* Vol. 69, pp. 333—42 and Vol. 71, p. 106 *et seq.*

(14) As to whether Dr Beddoe's reconstructed capacities have any relation absolutely or relatively to the true capacities of the individuals he has measured it is of course impossible to say. But we are in the unique position of being able to test his formula on the head of one of the most distinguished Englishmen not only of his own time, but of all time. For width of view, logical clearness, and intellectual grasp, there were but few Englishmen in his own day, and there have been few since, whom we can consider as surpassing Jeremy Bentham. Bentham died in June, 1832, and a few months before his death he prepared a monograph which was printed in a few copies only, one of which is preserved in the British Museum. It is entitled "Auto-Icon or the uses of the Dead to the Living; a fragment from the MSS. of Jeremy Bentham." The object of this work was to show "how, if embalmed, every man might be his own statue*." Bentham left not only his manuscripts but his body to University College, then the University of London, and his *Auto-icon* is now preserved there. The head is in a mummified condition, but as the accompanying plates from our photographs will show, gives one a fair appreciation of Bentham in his old age. We still see the "venerable locks which floated over his collar and down his back"—in the manner of the great German historian—locks which convince one of the difficulty attending any measurements of the arcs on the living head. The flesh, if dried, is still there in considerable thickness, and this and the hair render the determination of the inion as difficult, if not more difficult than in the case of the head of the living. The opisthion and basion are exposed, and except for a couple of wires crossing the brain cavity, there is little or no matter left inside the skull; in fact its capacity can be determined as accurately as that of the majority of skulls with which one is called upon to deal. Measurements of this head were taken by one of us. There was a marked projection at 65 mm. from the opisthion, which was selected as the inion. But to be quite sure of the matter Professor Thane was consulted, and he fixed on practically the same point. There was, however, a lower point at 51 mm. from the opisthion, and between these two points a groove could be distinguished. Whether these two points correspond to a superior and inferior inion it would not, perhaps, be possible to determine, even if the flesh were removed. Anatomical authority spoke strongly for the upper point as inion. We will refer

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[*] *Dict. Nat. Biography*, *sub* Jeremy Bentham.

to them as 'superior' and 'inferior' inions. We place here the values of the measurements taken on the Bentham head. Professor Thane with his usual kindness consented to take the critical arcs and diameters independently, and his measurements agreed within a millimetre with ours.

TABLE XV.

Measurements on the Head of Jeremy Bentham.

Auricular Height	121,	Less flesh	116,	Average	English ♂	115
Maximum Length	192	„	186	„	„	189
Maximum Breadth	153	„	147	„	„	141
Minimum Forehead Breadth	105	„	99	„	„	98
Bizygomatic Breadth	133 ?	„	127 ?	„	„	130
Horizontal Circumference	560	„	540 ?	„	„	524
Biauricular Arc	335	„	325 ?	„	„	308
Sagittal Arc to Opisthion	380	„	365 ?	„	„	377
„ „ 'Superior Inion'	315	„	300 ?	„	„	330
„ „ 'Inferior Inion'	330	„	315 ?	„	„	335
Opisthion to 'Superior Inion'	65	„	—	„	„	47
„ „ 'Inferior Inion'	51	„	—	„	„	42
Face Height	144 ?	„	—	„	„	—
Upper Face Height	73 ?	„	—	„	„	70
Total Height, Basion to Bregma	135	„	132	„	„	132
Skull Base, Nasion to Basion	105	„	102	„	„	102
Profile Length (Alveolar Point to Basion)	89 ?	„	—	„	„	96
Palate Length	47 ?	„	—	„	„	48
Palate Breadth	35 ?	„	—	„	„	37
Nasal Height	55 ?	„	—	„	„	51
Nasal Breadth	31 ??	„	—	„	„	24
Capacity	1475	„	—	„	„	1477
Profile Angle	93° ?	„	—	„	„	86°
Basal Angle	44°·5	„	—	„	„	41°
Nasal Angle	58°	„	—	„	„	65°
Alveolar Angle	77°·5	„	—	„	„	73°
Cephalic Index	79·7	„	79·0	„	„	75·0
Height/Length	70·3	„	70·9	„	„	70·0
Auricular Height/Length	63·0	„	62·4	„	„	60·6
Face Height/Bizygomatic Breadth	108	„	—	„	„	—
Upper Face Height/Bizygomatic Breadth	55	„	57·5	„	„	54
Nasal Index	56 ??	„	—	„	„	48
Palate Index	74·5	„	—	„	„	76

We place these measurements here because they may be of interest for other than our immediate purpose, merely remarking that difficulty of access or other reasons render some very doubtful. We notice at once that Jeremy Bentham's head is closely identical with that of the mediocre or average Englishman. Apparent exceptions are the very arcs which Dr Beddoe measures, but the difference here is, we believe, solely due to the difficulty of allowing for the flesh, and to a less extent for the hair. The only real exception we believe to be the profile angle, the face apparently receding from nasion to alveolar point. This receding character is undoubtedly exaggerated in the photograph, although great care was taken in the endeavour to get the 'horizontal plane' perpendicular to the vertical sides of the plate. Still, difficult as the determination of the lower rim of the orbit is in the present condition of the head, we believe the profile angle is truly greater than 90°, and that this is the case receives confirmation from the remarkable smallness of the nasal angle. With the exception of this receding character the head of this man of first-class intellect shows no single measurement—least of all its capacity—which would serve to differentiate it from that of the average Englishman of his time. Statistically, it is idle of course to argue from a single instance; but it is certainly worthy of note that Jeremy Bentham if judged by head-capacity would have been simply mediocre.

We have now to see what results the various reconstruction formulae as applied to Jeremy Bentham's measurements provide. We must note that all the measurements were taken and controlled by Professor Thane's independent measurements before any formulae were applied. To use Dr Lee's formula, the thickness of the flesh in its present condition at various points was tested by aid of a fine sharp needle. At the glabella it was 4 mm.; at the bregma 2 to 3 mm., and about the same over the back of the head. We accordingly took the cranial diameters to be $L=186$, $B=147$ and $H=116$ respectively. Applying Dr Lee's formula

$$C = {\cdot}000337 \times L \times B \times H + 406{\cdot}01,$$

we find:

$$C = 1475 \text{ cm.}^3.$$

To apply the General Formula of the present paper we roughly allowed for the flesh on the basis of a whole circumference for the horizontal circumference, and a half circumference for the sagittal and auricular arcs, taking as our values 540, 325 and 365 mm. This must give a value slightly too big, as we have not allowed for the hair. There results 1511 cm.^{3}. Now the actual capacity is certainly slightly over the measured value 1475 and almost certainly under 1495 cm.^{3}. The exact agreement of P and L with the measured capacity is of course only pure chance. But either P and L or $G.F.$ would suffice to show that Bentham had skull capacity close to the average English value. P and L is of course the more satisfactory because we have made no allowance that was not capable of measurement.

We now turn to Dr Beddoe's formula. We are to take $\frac{1}{3}$ of each of the arcs, divide the product by 2000, and add ·3 per cent. for each point of the cephalic index, about 50.

In applying this rule we will give Dr Beddoe every advantage, which he in his turn has not always given to those whom he criticises. Our auricular arc is measured with the head on the craniophor from the *top* of one auricular passage to the other. From the *centre* of one auricular passage to the other appears to be 343 mm. The horizontal circumference is 560 mm. and the nasion to the 'superior' inion 315 mm. The cephalic index is 79·7 points, say 30 above 50. The answer is:

$$C = 1221 \text{ cm.}^3.$$

To give Dr Beddoe more grace, suppose, which is extremely improbable, that the 'inferior' inion is to be taken as the true inion. The sagittal arc is now 330 instead of 315 and the answer is:

$$C = 1280 \text{ cm.}^3.$$

But we will go even further. Dr Beddoe makes light of the hair when measuring his arcs and therefore he cannot consider of much importance the variation in the flesh. We will, however, endeavour to improve his position by allowing for the effect of shrinkage of the flesh on his circumferences, although we believe that this shrinkage is not comparable with the effect of different states of the hair. It can only be the roughest approximation. A circle of radius $r + 5{\cdot}5$ mm. has for circumference $2\pi(r + 5{\cdot}5)$ mm. Hence, if 5·5 mm. shrink to 3 mm. there would be a drop of $2\pi \times 2{\cdot}5$ mm. in the circumference, say 16 mm. Hence, at the outside we cannot allow more than 16 mm. for change in the horizontal circumference due to shrinkage, and possibly 10 mm. in the auricular arc, and say 13 in the sagittal. This gives us as measurements in life:

576, 353 and 328 for 'superior' inion,
576, 353 and 343 for 'inferior' inion.

The first and more probable inion gives us now:

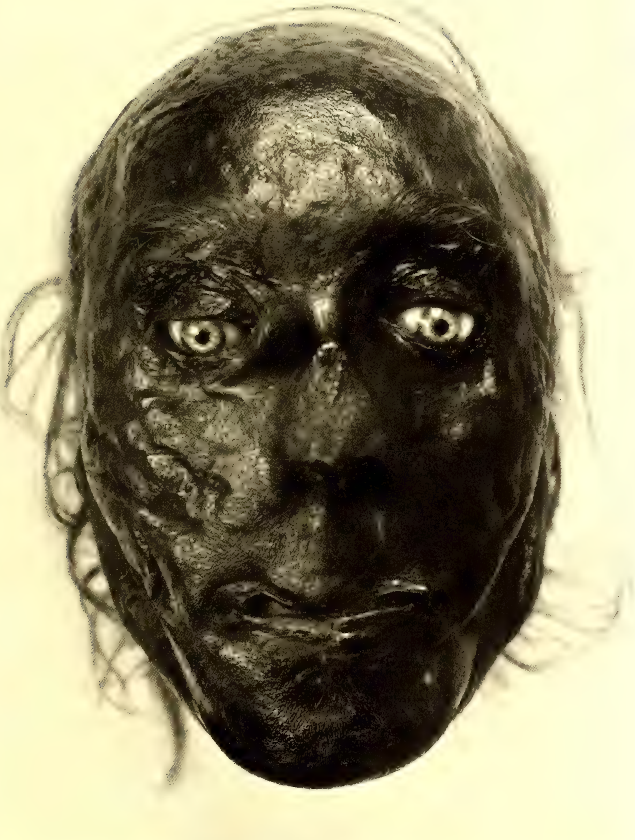
$$C = 1346,$$

and the second and improbable inion:

$$C = 1408.$$

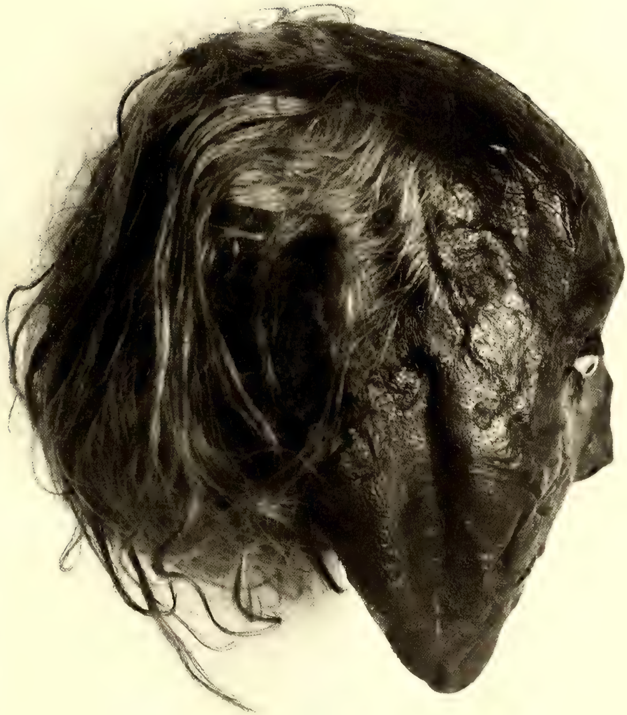
Dr Beddoe's estimate would then be at least 70 cm.^{3}, but most probably 150 to 200 in defect, in the case of Jeremy Bentham! This would not only place Bentham, undoubtedly as able as, if not abler than anybody on Dr Beddoe's list, at the very bottom of it, but a long way below the mediocre Englishmen with whom he is really identical. Thus, it seems to us, that in the only case wherein we have been able to test Dr Beddoe's formula and his hypothesis of marked correlation between skull capacity and ability both fail completely. This may be only the exception which proves the rule, but we must confess that it makes us entirely distrust not only his guesswork formula, but the deductions as to ability and skull capacity which he has based upon it.

(15) *Conclusion.* In concluding this paper we want particularly to emphasize one or two points. We are not defending a particular formula; we believe, owing to the results obtained, that a circumferential formula as good as a diametral formula can be reached. We are not fighting a particular group of workers; in particular we believe that Dr Beddoe has done good service in widening the field of anthropometric interest in this country. What we want to emphasize are the following principles:



Auto-icon of Jeremy Bentham.

Front View.



Auto-icon of Jeremy Bentham.

Profile.

(*a*) Statistical enquiry is not a field for guesswork and elementary arithmetic; there is a mathematical science of statistics which must be learnt, and papers dealing numerically with anthropometric and craniometric data which do not now apply this theory are simply outside the field of science.

(*b*) Method in statistical reduction is not the only thing we demand however. In the light of modern scientific enquiry we demand that the craniologist shall distinguish between what holds for a local race of man, and what may be applied to mankind as a whole. We have elsewhere shown* by actual measurements that inter-racial and intra-racial correlations are not the same, and consequently the reconstruction formula for the individual within a given race is not the same as the formula for reconstructing the mean of a given race.

Dr Beddoe draws no distinction here, just as he draws no distinction between the sexes, although Dr Lee gives every warning on this point. It is only when we find local race formulae closely in agreement among themselves that we can extend our results and form from them an inter-racial formula. Dr Beddoe makes no attempt to deduce intra-racial formulae from fairly homogeneous racial series by recognised statistical methods; he does not then compare these among themselves and see whether an inter-racial one can be deduced from them. He simply makes a guess, tries it on a most heterogeneous series, and if it does not fit makes another guess. He applies Dr Lee's results regardlessly to individuals and to race-means, he uses the same formula for male and female skulls, and where he has no data to offer, although by time and patience he could have collected some, he simply makes the roughest appreciation. This is not science; it is the dilettantism which in the past has made anthropometry and craniometry impossible subjects for academic study. We believe that the time has come to change this, and uphill as the battle will be we shall not hesitate to criticise in the strongest manner papers like Dr Beddoe's, which sensibly lower the already low standard of craniometric science.

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* *Biometrika*, Vol. II. pp. 347—56.

ÉTUDE BIOMÉTRIQUE SUR LES VARIATIONS DE LA FLEUR ET SUR L'HÉTÉROSTYLIE DE *PULMONARIA OFFICINALIS* L.

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INTRODUCTION.

Ce travail est relatif à la Pulmonaire officinale. Nous avons l'intention de l'étendre à d'autres plantes à fleurs hétérostylées en vue de contribuer à la connaissance du phénomène intéressant de l'hétérostylie.

Plusieurs herborisations nous avaient montré, chez *Pulmonaria officinalis*, de grandes variations dans la longueur des styles de chacun des deux types brachystylé et dolichostylé. Fig. 1.

Nous nous sommes proposé

(1) D'étudier, par des mensurations nombreuses, la morphologie de la fleur et l'hétérostylie de *Pulmonaria officinalis* L., pour en dégager des données numé-

riques précises sur le type moyen de chaque organe, sa fixité relative, et l'étendue de ses variations possibles.

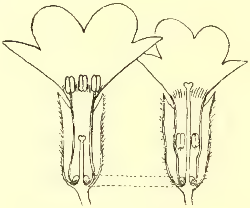

Fig. 1. *Pulmonaria officinalis* Gr. 2/1.
(d'après Hildebrand, Botanische Zeitung, 13 janv. 1865).

(2) De déterminer la nature des courbes, relatives à la variation de longueur des organes des deux types d'une fleur hétérostylée.

(3) D'établir si, en des localités différentes, le type floral subit des modifications de races orientées dans un sens déterminé, et si on retrouve le même type moyen et la même loi de fréquence.

Cette dernière question, on le voit, présente un certain intérêt au point de vue de la géographie botanique. C'est seulement à l'aide des études biométriques comparées, qu'il est possible de dégager, d'une part l'étendue de la variation possible d'une espèce dans les diverses localités de sa station habituelle, d'autre part de déterminer dans quel sens la variation a une tendance à s'accentuer.

Ces mesures biologiques ont en outre l'avantage de laisser des documents statistiques sur l'état d'une espèce qu'il peut être intéressant d'étudier à nouveau plus tard, au point de vue de son évolution possible.

Avant d'aborder ce travail je tiens à reconnaître combien j'apprécie l'honneur de le voir inséré en langue française dans *Biometrika*. Je veux aussi rendre un hommage de reconnaissante gratitude et de remerciements à M. le *Professeur W. F. R. Weldon*. Non content de revoir mon manuscrit, mon savant confrère a bien voulu m'aider de sa critique et de sa collaboration précieuse dans la tâche ingrate du calcul mathématique de nombreuses données numériques. C'est pour moi un devoir de le reconnaître ici et de l'en remercier chaleureusement.

Historique.

En réalité, nous possédons bien peu d'études de biométrie florale. Deux auteurs, Darwin* et Hildebrand†, pourtant, à propos des Pulmonaires, ont été amenés à dire quelques mots sur les différences florales observées entre les fleurs brévistylées ou brachystylées et les fleurs du type dolichostylé ou brévistémoné. Mais ce qui préoccupait ces auteurs c'était la question de la fécondité relative des deux types de fleurs, et aucune statistique, ni aucun graphique n'ont appuyé leurs observations sur les dimensions des organes floraux.

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* Ch. Darwin, *Des différentes formes des fleurs dans les plantes de la même espèce*, trad. Heckel, p. 110. Reinwald, 1878.

† Hildebrand, *Die Geschlechter-Vertheilung bei den Pflanzen*, 1867, p. 37; *Botanische Zeitung*, 1865, 13 janvier, p. 13.

Voici d'ailleurs les seules données signalées par eux :

Chez *Pulmonaria officinalis*, le pistil de la forme dolichostylée, dit Darwin, est deux fois aussi long que celui de la forme brachystylée, et les étamines diffèrent d'une manière correspondante quoique inverse.

Les grains polliniques sont différents dans les deux sortes. Ceux de la première forme sont à ceux de la seconde comme 78 est à 100 en longueur, 6 à 7 en épaisseur.

La corolle est plus grande généralement dans les fleurs brachystylées (et c'est l'inverse chez *Pulmonaria angustifolia*).

Hildebrand a ramassé dans le Siebengebirge 10 *Pulmonaria officinalis* de chaque sorte.

Les 10 dolichostylées ou brévistémonées portaient 289 fleurs, les 10 brachystylées ou brévistylées en portaient 373.

Hildebrand conclut de là que les sujets brachystylés produisent beaucoup plus de fleurs. La conclusion est basée comme on le voit sur un nombre très petit d'observations. Darwin reconnait d'ailleurs que 10 plantes anglaises dolichostylées, examinées par lui, furent très fécondes après fécondation illégitime, tandis que les 10 plantes semblables, récoltées en Allemagne par Hildebrand, restèrent complètement stériles. Cette différence semble indiquer une certaine variabilité de la fertilité.

Les plantes de Darwin cultivées en plein air ne montrèrent aucune tendance à devenir isostylées, et à perdre leur propre caractère dolichostylé, comme cela ce présente souvent parfois sous l'influence de la culture, dans plusieurs espèces hétérostylées de Primula.

Darwin signale la grande variété de longueur du pistil et des étamines de *Primula angustifolia*, et trouve que, chez cette plante, la distance entre les anthères et le stigmate n'est pas constante ; d'une moyenne de 7 mensurations seulement il conclut que cette distance dans la forme dolichostylée est à cette de la forme opposée comme 100 est à 69. Les longueurs relatives moyennes des pistils de ces deux formes seraient entre elles comme 100 est à 56, et pourraient atteindre même le rapport $\frac{100}{33}$. Cette variation si accentuée fait soupçonner à Darwin un état de transition et une tendance de la plante à devenir dioïque.

D'autre part Hildebrand signale que *Pulmonaria azurea* n'est point hétérostylée.

Les quelques mensurations, signalées ci-dessus, semblaient démontrer que l'hétérostylie était le mieux fixée chez *P. officinalis* pour diminuer de régularité chez *P. angustifolia* et disparaître chez *P. azurea.*

Généralités.

Prenons un nombre N d'échantillons de fleurs de Pulmonaires. Supposons qu'il s'agisse d'établir le type de fréquence et le type de longueur moyenne du style de ces fleurs.

Nous mesurons les styles. Ayant porté sur l'axe des abcisses les longueurs en millimètres exprimant la taille, nous élevons, aux divers points, des ordonnées de hauteurs proportionnelles aux nombres d'individus correspondants.

Lorsqu'on étudie comparativement des fleurs provenant de localités différentes il faut naturellement autant que possible prendre le même nombre d'échantillons de chaque localité. Une restriction pourtant doit être faite. Il y a souvent plus d'avantage à prendre le plus grand nombre possible.

La variation de longueur du style n'est pas discontinue. Dans nos mensurations nous avons ordinairement pris comme unité le $\frac{1}{2}$ millimètre. Vu le grand nombre d'échantillons à mesurer, il ne pouvait être question d'employer la loupe, il fallait donc choisir une unité facile à lire à l'œil nu avec une approximation suffisante. Mais, les abscisses ne croissent pas en réalité de $\frac{1}{2}$ en $\frac{1}{2}$ millimètres, mais bien de quantités infiniment petites, c'est-à-dire de x à $x + dx$.

En joignant le haut des ordonnées, le graphique que nous obtiendrons sera donc un polygone de variation (Pearson) qui tend seulement vers la courbe limite de ce polygone. Ainsi il y a intérêt à prendre un nombre le plus grand possible d'individus afin d'esquisser le mieux possible les vrais contours du polygone théorique artificiellement obtenu qui doit renseigner sur la courbe.

Pour donner une idée de l'approximation relative qu'il est possible d'obtenir avec *un petit nombre* de 25 exemplaires, nous donnons ci-après (fig. 2*a*) une courbe tracée avec deux lots de 25 plantes et celle qu'on obtient avec 31 plantes dont on a déterminé la distance du stigmate à l'anthère. Ces plantes ont été récoltées à des distances de 3 mètres au moins, au hasard des rencontres. Une fleur de chaque pied a été mensurée.

Plus le nombre des individus s'accroît, plus la courbe a une tendance à monter vers les ordonnées de grande fréquence, mais les parties latérales correspondant aux faibles fréquences restent partiellement indéterminées et s'étendent de plus en plus loin.

La courbe A (31 pl.) est enveloppante vis-à-vis des deux autres B et C. Elle s'étend de a en g. La courbe B a les mêmes valeurs extrêmes enregistrées, mais la courbe c commence seulement en b pour finir en g.

Néanmoins, malgré les différences, ces trois courbes ont bien la même allure, avec le même type de plus grande fréquence placée en d, et avec les mêmes inflexions générales en c et f. Il est vraisemblable que la courbe limite de ces polygones est une courbe binomiale normale n'ayant qu'un sommet principal S. Les deux sommets secondaires s', s'' ne se maintiennent pas quand on dispose de 200 mesures différentes.

Ainsi les graphiques obtenus, dans ce qui va suivre, doivent parfois être interprétés par suite de l'insuffisance relative du nombre des mesures enregistrées.

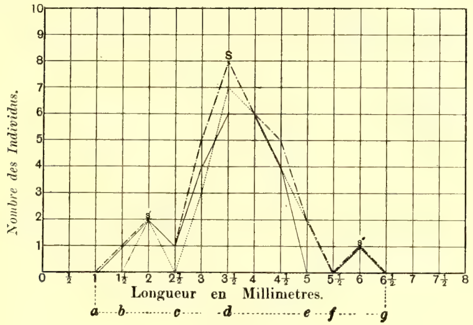

FIG. 2*a*.

A. —·—·— Courbe tracée avec 31 plantes.
B. ———— Courbe tracée avec 25 plantes.
C. ·········· Courbe tracée avec 25 autres plantes.
Laxou. 31—25 plantes isolées de 3 mètres (brévistémonées).
Distance du stigmate à l'anthère.

Même en opérant avec 25 ou 30 échantillons seulement, il y a des polygones de fréquence qui sont souvent très voisins de la courbe limite. L'allure générale du périmètre du polygone renseigne dans ce cas par sa régularité qui n'est évidemment pas l'effet du hasard. Nous l'avons vérifié plusieurs fois pratiquement en comparant deux graphiques obtenus par exemple avec 30 et 140 échantillons différents. Dans le cas des courbes polymorphes il y a parfois une certaine incertitude dans l'interprétation du polygone[*], mais dans ce qui va suivre la nature de la courbe est généralement non douteuse, et nous n'avons pas rencontré de courbes de cette dernière catégorie.

Le présent travail apportera donc une solution à la question suivante qui n'a pas encore été abordée je crois :

> Quelles sont les diverses courbes des variations de longueur des organes d'une fleur hétérostylée ?

L'hétérostylie est en somme une question de longueurs relatives de deux organes. Le dispositif présente une importance physiologique établie par les recherches sur le croisement[†] ; on peut penser que l'hétérostylie se maintient par suite de conditions particulières dont on peut espérer lire l'existence dans les mesures biométriques.

Avant d'entreprendre ces recherches je pensais, par analogie avec d'autres faits biologiques, qu'un dispositif comme l'hétérostylie ne pouvait sans doute se maintenir que par suite d'une variation unilatérale. Je supposais que quelques unes des courbes, comme, par exemple, celle qui concerne la distance du stigmate à l'anthère, auraient probablement l'ordonnée maximum à une extrémité de leur étendue, comme dans celles qui sont appelées, à tort par de Vries, demi-courbes Galtoniennes. Comme on le verra par la suite, cette hypothèse était fausse*. Les graphiques sont formels à cet égard.

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[*] Ludwig, *Bot. Centralblatt*, 1893, 1895. C. B. Davenport, *Statistical Methods.*

[†] Darwin, *Fécondation croisée. Forme des fleurs.*

Pour arriver à apprécier la fixité relative de l'hétérostylie il faut calculer la valeur moyenne de chaque caractère floral, c'est-à-dire établir son type de longueur moyenne, et puis le carré moyen des déviations $= \sqrt{\frac{\Sigma\,(d^2)}{N}}$.

Pour un nombre N d'échantillons, soit m les mesures en $\frac{1}{2}$ millimètres, et n les nombres exprimant la fréquence de chaque mesure m,

$$\text{La longueur moyenne sera } L = \frac{\Sigma\,(mn)}{N}.$$

En somme, L est une moyenne arithmétique de toutes les longueurs observées.

D'autre part le type *le plus fréquent* a une longueur K qui est aussi caractéristique des tendances de la race.

Si donc les deux longueurs L et K sont différentes il faut tenir compte des deux pour apprécier la fixité du caractère.

Un exemple graphique fait mieux comprendre cette conclusion : Soient A, B, C trois courbes de fréquence obtenues avec les styles de trois lots de Pulmonaires de trois localités différents :

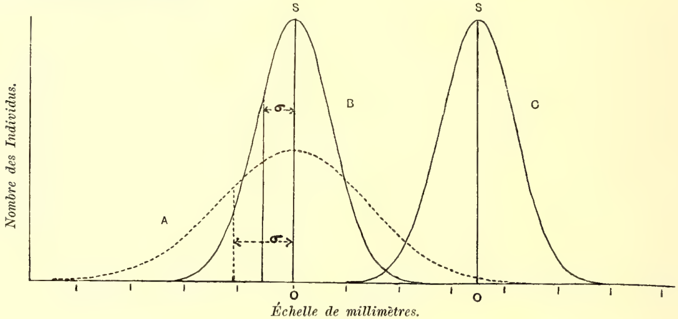

FIG. 2 *b*.

Les courbes A et B enferment deux surfaces égales et symétriques par rapport aux axes de grande fréquence qui sont superposés en OS. Elles limitent des polygones de fréquence très différents d'aspect. Le type théorique moyen reste le même.

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* Ce n'est pas un cas particulier à la Pulmonaire. Nous publierons ultérieurement une étude biométrique sur la Primevère qui aboutit à cette même conclusion.

La race n'a pas varié de type. Il existe naturellement un nombre indéterminé de courbes de même surface que A et B, et intermédiaires de forme, et auxquelles la conclusion ci-dessus s'applique aussi.

Si la valeur moyenne de la race n'a pas varié, en A et B, il n'est pourtant pas sans intérêt d'enregistrer deux faits:

(1) Dans la station B les individus sont peu variables et leur type de styles est concentré autour d'une longueur moyenne dont ils s'écartent peu;

(2) Dans la station A les individus ont une longueur des styles qui est très variable et il y a en quelque sorte un affolement du type. Si celui-ci persiste il y a ici une sorte de race géographique différente de l'autre.

Les courbes B et C enferment deux aires égales, et les polygones de fréquence sont identiques et superposables. Le type moyen est très différent en B et C. Il est passé de 5 à 8½, soit une variation, de la taille de la race, qui est une augmentation de plus de 50 p. 100 de sa taille initiale.

Dans une courbe établie à l'aide d'échantillons de localités différentes, il faut donc examiner si, dans les divers lieux, l'ordonnée de plus grande fréquence est déplacée à gauche ou à droite. Dans le travail qui suit, on a cherché à définir le type de longueur moyenne théorique, obtenu à l'aide de mensurations nombreuses dont on prend la moyenne arithmétique. Ce type moyen peut ne pas être le type de plus grande fréquence.

Il ne peut s'en éloigner beaucoup, si la courbe est sensiblement du type des courbes binomiales normales, ou des courbes hyperbinomiales, c'est-à-dire monomorphes, bilatérales et symétriques. Dans le cas d'une courbe parabinomiale, c'est-à-dire dont l'ordonnée de plus grande fréquence est rejetée d'une côté, le type moyen est fixé par l'ordonnée qui divise le polygone de fréquence en deux parties égales, et cette ordonnée n'est jamais la même que celle qui correspond au type le plus fréquent.

Cette dernière est évidemment aussi caractéristique de la race que l'ordonnée du type moyen; son simple déplacement, sans déformation considérable de la courbe parabinomiale, est une indication certaine de la variation de la race.

Pour construire la courbe qu'on pourra regarder comme représentant la limite théorique du polygone des observations, nous avons adopté la formule symétrique de Gauss, à cause de la symétrie de la plupart des polygones obtenus. Avec le nombre restreint d'échantillons de chaque sorte étudiés, il était inutile d'essayer les formules plus compliquées de Pearson*. Voici donc les quantités que nous avons calculées, pour représenter chaque polygone par la courbe exponentielle de Gauss,

$$y = \frac{N}{\sqrt{\mu\pi}} e^{-\frac{x^2}{\mu}}.$$

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* *Phil. Trans.* 1895, et *Biometrika*, *passim*.

Nous devons d'abord calculer la valeur moyenne du caractère étudié; soit m_1, m_2, etc., les diverses valeurs individuelles dans la série N d'échantillons, nous avons, pour trouver M, la valeur moyenne,

$$M = \frac{\Sigma(m)}{N}.$$

Les valeurs de x dans la formule de Gauss sont les écarts individuels, c'est-à-dire les différences entre les mesures individuelles et la valeur moyenne de la série, ou les valeurs de $(m-M)$. Puisque la valeur la plus grande de y est obtenue en mettant $x=0$ dans la formule, on voit que la valeur la plus fréquente de la série étudiée doit être la valeur moyenne. Dans les cas où la valeur moyenne ne se trouverait pas plus fréquente qu'aucune autre, on devrait employer l'une ou l'autre des formules asymétriques développées par Pearson (*loc. cit.*).

Pour calculer la quantité μ, on doit calculer la somme des carrés des écarts du moyen, ou la valeur du

$$\Sigma\{(m-M)^2\}:$$

et nous avons

$$\mu = 2\frac{\Sigma\{(m-M)^2\}}{N}.$$

Selon la notation d'Amann (*Journal de Botanique*, T. 13) on pourra écrire

$$\frac{\Sigma\{(m-M)^2\}}{N} = Q^2,$$

et suivant la notation de Pearson on écrira $Q=\sigma$ (index de variabilité).

L'écart probable, la valeur P d'Amann, l'écart quartile de Galton, se trouve facilement par la relation

$$P = 0{\cdot}6745\sigma = 0{\cdot}4769\mu.$$

Dans les tableaux insérés dans ce travail on a donné une importance peut-être exagérée à l'*étendue empirique de la variation*, telle qu'elle résulte souvent d'un très petit nombre d'observations. On a voulu ainsi simplement donner aux botanistes des renseignements concrets sur ce qu'on pouvait s'attendre à rencontrer dans des herborisations analogues aux nôtres. Mais nous n'oublions pas pour cela que cette étendue empirique de la variation *ne doit pas être considérée comme une caractéristique du mode de variation*, parce qu'elle est trop exposée à être modifiée par des causes accidentelles, différentes dans chaque série d'observations. En d'autres termes la loi de variation n'est pas changée parce que les limites enregistrées apparaissent dissemblables dans deux prises successives d'échantillons*.

Il y a lieu au contraire d'attacher de l'importance à l'*étendue théorique de la variation* telle qu'elle se déduit des propriétés caractéristiques de l'exponentielle; et, chaque table de l'intégrale de la Probabilité (celle de Bertrand, par exemple, ou celle de Sheppard) nous montre que pour une valeur quelconque de μ ou de σ l'étendue de la variation tend toujours à grandir, quand le nombre des individus étudiés devient plus grand.

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* Duncker, *Biolog. Centralblatt*, Bd. XVIII. No. 15, S. 569.

Prélèvement des fleurs.

Chaque fleur a été prélevée sur une hampe différente. On sait que chaque hampe florale porte des fleurs du même type morphologique : nous avons plusieurs fois contrôlé ce fait par des mesures précises. Il y a donc une sorte de caractéristique individuelle. Si, par exemple, la fleur bien épanouie, prise comme type, est du type à style exserte par rapport au calice ; on peut constater le même caractère chez les autres fleurs du même pied.

Cette constatation initiale nous a servi de base pour étendre considérablement la portée des statistiques faites. Si les fleurs d'un pied avaient eu des caractéristiques différentes, il eut fallu les mesurer toutes pour en dégager la notion de variabilité maximum. Comme chaque plante possède une moyenne de 13 à 15 fleurs, les mensurations eussent dû être, nécessairement, 13 à 15 fois plus nombreuses pour donner la même approximation que celle que nous avons obtenue.

Le nombre des mesures qui servent de base à ce travail est de près de 5000. Ces mesures ont été fournies par environ un millier de hampes florales.

Prélèvement des échantillons.

On a employé trois méthodes différentes pour choisir les hampes florales qui devaient fournir chacune une fleur à la mensuration.

1ère *méthode.* Elle consiste à explorer une localité de surface limitée (par exemple, 200 à 500 mètres carrés suivant la rareté) et à y prélever toutes les hampes florales sans exception.

Si un rhizôme émet plusieurs hampes, celles-ci doivent présenter une grande ressemblance puisqu'elles proviennent d'une même graine mère. Chaque individu est donc représenté dans la statistique par un nombre de hampes qui est variable.

Cette méthode de prélèvement présente en outre l'inconvénient suivant : Elle suppose que les types brévistylés et les types brévistémonés sont aussi prolifiques au point de vue du nombre des hampes. S'ils ne le sont pas il semble qu'il y ait là une cause qui altère la rigueur de la biométrie comparée des deux types.

2^{e} *méthode.* On prélève comme précédemment, et dans le lot on prend, au hasard, seulement une partie des plantes.

3^{e} *méthode.* On prélève les hampes sur un espace plus grand, en ne ramassant, au hasard, que des hampes espacées de deux ou trois mètres de distance. De cette façon on ne recueille qu'un échantillon de chaque individu issu d'une graine Toutes les hampes récoltées proviennent d'individus et de graines différentes.

Nous avons dressé des graphiques qui permettent de conclure que les trois méthodes peuvent donner des résultats comparables.

La 3^e méthode exige pourtant moins d'échantillons différents pour dégager la loi de variation de chaque organe.

Elle est donc supérieure aux autres, et c'est celle que nous avons employée pour la biométrie comparée des Pulmonaires de 4 stations différentes.

Pour distinguer sûrement *P. officinalis* de l'espèce voisine, *P. tuberosa* (var. *latifolia* et var. *angustifolia*), le caractère qui a été choisi a été le suivant : *Carpelles mûrs—aigus au sommet.* La Pulmonaire à racines tubéreuses a, au contraire, des carpelles *arrondis* au sommet. Cette dernière est d'ailleurs beaucoup moins commune que l'autre dans les bois du calcaire jurassique des environs de Nancy.

Plan du travail.

Voici l'ordre des questions abordées :

1. Influence de la taille de la plante sur les dimensions florales. (Plantes récoltées à Maxéville en 1902.)

2. Comparaisons biométriques entre les fleurs brévistémonées et les fleurs brévistylées d'une même localité. (Maxéville, 1903, et Messein, 1903.)

3. Étude comparée des plantes récoltées à plusieurs reprises dans une localité, en 1902 et 1903 (Maxéville), en vue de voir si le climat annuel exerce une influence.

4. Étude comparée des plantes de quatre stations, récoltées la même année dans des localités très différentes d'exposition. (Maxéville, Messein, Laxou, Malzéville.)

5. Conclusions.

I.

INFLUENCE DE LA TAILLE DE LA PLANTE SUR LA VARIATION DE LA FLEUR.

Le calice de la Pulmonaire officinale est, comme on le sait, gamosépale, et d'un aspect très comparable dans les deux types brévistylé et brévistémoné. Il est renflé et pourvu de cinq lobes dont la hauteur est à peu près de $\frac{1}{4}$ ou $\frac{1}{3}$ de la hauteur totale du calice. Les mensurations ont porté sur la hauteur totale du calice mesuré dans son axe de symétrie.

Les lobes du calice sont de dimensions assez variables pour des calices de même hauteur totale. Voici les deux types extrêmes : Deux calices de 14 millimètres de hauteur totale peuvent être fendus de 6 ou de 3 millimètres seulement. Les dimensions extrêmes de hauteur du calice sont de 8 et 17 millimètres. Le calice, notamment, plus que les autres parties de la fleur, semble devoir varier un peu suivant la vigueur des individus, comme le font les feuilles.

Il est donc nécessaire de rechercher si, aux variations de taille et de vigueur des tiges, correspondent des variations de dimensions pour les diverses parties de la fleur hétérostylée.

Nos mensurations ont porté sur 25 très grandes plantes, et 25 très petites, choisies dans une récolte de plusieurs centaines d'individus brévistémonés d'une localité.

Les grandes tiges avaient 19 à 25 cm. de hauteur.

Les petites tiges atteignaient seulement une hauteur de 8 à 15 cm.

On a prélevé une fleur épanouie et bien développée dans l'inflorescence du sommet de la tige de chaque plante.

Les tables de statistique I et II donnent les mesures enregistrées. Voyez figs. 7—12.

TABLE I.

Mesures de 25 grandes plantes choisies pour leur grande taille (*Maxéville,* 1902).
(Valeurs en millimètres.)

	1	2	3	4	5		6		7	8	
Nos.	Hauteur des tiges (cm.)	Hauteur du calice (mm.)	Hauteur du stigmate au-dessus de la base du calice	Longueur du style au-dessus de l'ovaire	Distance du stigmate au bord du calice. Style		Hauteur du haut des étamines au-dessus de la base		Distance du stigmate à l'anthère	Nombre de fleurs	
					Inclus dans le calice de	Exserte du calice de	De la corolle	Du calice		Par infl.	Total
1	19	13½	12½	10½	1	—	5	6	6½	7+7	=14
2	21	14½	13½	11½	1	—	7	8	5½	9, 6, 5	20
3	20	13½	12½	10½	1	—	6	7	5½	6, 9	15
4	20	11	12	10	—	1	5	6	6	6, 6	12
5	19	13½	12	10	1½	—	5	6	6	7, 8	15
6	22	13	12	10	1	—	7	8	4	6, 10	16
7	20	12½	12	10	½	—	5½	6½	5½	7, 6	13
8	20	12½	11½	9½	1	—	6	7	4	7, 12	19
9	19	13½	11½	9½	2	—	6	7	4½	6, 9	15
10	20	12	11	9	1	—	5	6	5	8, 11	19
11	20	14½	13½	11½	1	—	7	8	5½	7, 9	16
12	20	12	11½	9½	½	—	5½	6½	5	7, 4	11
13	20	13	11	9	2	—	6	7	4	6, 7	13
14	20	11½	11½	9½	—	—	6	7	4½	6, 9	15
15	25	12	13	11	—	1	5½	6½	6½	6, 7	13
16	20	11	11	9	—	—	5½	6½	4½	5, 9	14
17	19	11	11	9	—	—	5	6	5	8, 5	13
18	19	12½	12	10	½	—	5	6	6	6, 8	14
19	23	11½	12	10	—	½	7	8	4½	9, 8	17
20	23	12	12	10	—	—	5½	6½	5½	7, 10	17
21	19	12	11½	9½	½	—	5	6	5½	6, 15	21
22	23	14½	12	10	2½	—	6	7	5	5, 6	11
23	20	12	12½	10½	—	½	6½	7½	5	7, 5	12
24	19	12	11	9	1	—	6½	7½	3½	7, 9	16
25	22	12	12	10	—	—	6	7	5	6, 11	17
Variation	19—25	11—14½	11—13½	9—11½	−2½ à	+1	5—7	6—8	3½—6½	—	378

TABLE II.

Mesures de 25 petites plantes choisies pour leur petite taille (*Maxéville*, 1902). (Valeurs en millimètres.)

	1	2	3	4	5		6		7	8	
Nos.	Hauteur des tiges (cm.)	Hauteur du calice (mm.)	Hauteur du stigmate au-dessus de la base du calice	Longueur du style au-dessus de l'ovaire	Distance du stigmate au bord du calice. Style		Hauteur du haut des étamines au-dessus de la base		Distance du stigmate à l'anthère	Nombre de fleurs	
					Inclus de	Exserte de	De la corolle	Du calice		Par infl.	Total
1	8	12	12	10	—	—	5	6	6	6+7	=13
2	12	16½	13	11	3½	—	6½	7½	5½	6, 9	15
3	13	14	13	11	1	—	6½	7½	5½	7, 10	17
4	13	11	13½	11½	—	2½	7	8	5½	7, 1	8
5	13	12½	12½	10½	—	—	6	7	5½	8, 8	16
6	11	12	11	9	1	—	5	6	5	7, 8	15
7	15	15	14	12	1	—	6½	7½	6½	9, 2	11
8	10	12	12	10	—	—	5	6	6	8, 5	13
9	15	16	13	11	3	—	6	7	6	6, 1	7
10	13	12½	10½	8½	2	—	5½	6½	4	7, 9	16
11	12	13½	12½	10½	1	—	5½	6½	6	6, 9	15
12	11	11½	12	10	—	½	6	7	5	3, 0	3
13	11	13½	12	10	1½	—	6	7	5	6, 0	6
14	14	9½	11½	9½	—	2	6½	7½	4	6, 7	13
15	13	12	12	10	—	—	6	7	5	6, 7	13
16	13	12½	12	10	½	—	6	7	5	8, 11	19
17	14	13	12½	10½	½	—	7	8	4½	7, 7	14
18	14	13	12½	10½	1	—	6½	7½	5	7, 3	10
19	13	14	12	10	2	—	6	7	5	7, 19	26
20	15	13	13	11	—	—	5½	6½	6½	6, 9	15
21	14	10½	11	9	—	½	6	7	4	7, 10	17
22	14	14½	13½	11½	1	—	7	8	6	5, 9	14
23	14	11½	13	11	—	1½	6½	7½	6½	7, 8	15
24	14	12	11	9	1	—	5½	6½	4½	7, 9	16
25	14	12	13	11	—	—	6	7	6	6, 7	13
Variation	8—15	9½—16½	11—14	8½—12	−3½ à	+2½	5—7	6—8	4—6½	—	340

Pour comparer avec les plantes brévistémonées voici les mensurations de 2 grandes plantes brévistylées et de 2 petites brévistylées prises au hasard. (Nous n'avons pas cru nécessaire de faire à leur sujet un examen de 50 échantillons.)

TABLE III.

Plantes brévistylées choisies pour leur grande ou leur petite taille (*Maxéville*, 1902).
(Valeurs en millimètres.)

	Hauteur des tiges (cm.)	Hauteur du calice (mm.)	Hauteur du stigmate au-dessus de la base du calice	Longueur du style au-dessus de l'ovaire	Distance du stigmate au bord du calice	Hauteur du haut des étamines au-dessus de la base		Distance du stigmate à l'anthère	Nombre de fleurs
						De la corolle	Du calice		
Grandes plantes brévistylées	25	13	7	5	6	12	13	5	8+10=18
	22	13	$6\frac{3}{4}$	$4\frac{3}{4}$	$6\frac{1}{4}$	12	13	$5\frac{1}{4}$	8+ 9=17*
Petites plantes brévistylées	12	13	6	4	6	$11\frac{1}{2}$	$12\frac{1}{2}$	$5\frac{1}{2}$	7+6=13
	12	12	7	5	5	12	13	5	7+9=16†

TABLE IV.

Pulmonaires brévistémonées. Variations comparées de 25 grandes et de 25 petites plantes (*Maxéville*).

Catégories	Grandes plantes hauteur = 19—25 cm.	Petites plantes hauteur = 8—15 cm.
Proportion centésimale de styles exsertes par rapport au calice	16 p. 100	20 p. 100
styles égaux au calice ...	20 ,,	24 ,,
styles inclus dans le calice	64 ,,	56 ,,
Hauteur du calice (chiffres extrêmes enregistrés)	11 à $14\frac{1}{2}$ millimètres	$9\frac{1}{2}$ à $16\frac{1}{2}$ millimètres
Hauteur du stigmate au-dessus de la base du calice	11 à $13\frac{1}{2}$,,	11 à 14 ,,
Longueur du style au-dessus de l'ovaire ...	9 à $11\frac{1}{2}$,,	$8\frac{1}{2}$ à $11\frac{1}{2}$,,
Distance du stigmate au bord du calice ...	$-2\frac{1}{2}$ à $+1$,,	$-3\frac{1}{2}$ à $+2\frac{1}{2}$,,
Hauteur du haut des étamines au-dessus de la base du calice	6 à 8 ,,	6 à 8 ,,
Distance du stigmate à l'anthère	$3\frac{1}{2}$ à $6\frac{1}{2}$,,	4 à $6\frac{1}{2}$,,
Nombre de fleurs par inflorescences ...	4 à 15 fleurs	1 à 19 fleurs
Nombre de fleurs par individu	11 à 21 ,,	3 à 19 ,,
Nombre de fleurs pour 25 individus ...	378 ,,	340 ,,
Nombre moyen de fleurs par individu ...	15, 12	13, 60

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* Soit 17·5 fleurs par plante.

† Soit 14·5 fleurs par plante.

TABLE V.

P. officinalis (*Maxéville* 1902).—*Plantes brévistémonées.* Fig. 8.

Hauteur totale du calice.—Nombre de plantes présentant les diverses hauteurs (pour 25 observations de chaque série).

	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	15½	16	16½	17	Millimètres
Grandes plantes (Table I, col. 2)	—	—	—	—	3	2	8	3	2	4	—	3	—	—	—	—	—	Nombre de plantes
Petites plantes (Table II, col. 2)	—	1	—	1	1	2	6	3	3	2	2	1	1	—	1	1	—	,,

Hauteur du style au-dessus de l'ovaire.—Fréquence relative pour 25 observations. Fig. 10.

	8	8½	9	9½	10	10½	11	11½	12	12½	13	Millimètres
Grandes plantes (Table I, col. 4)	—	—	4	6	9	3	1	2	—	—	—	Nombre de plantes
Petites plantes (Table II, col. 4)	—	1	3	1	7	4	6	2	1	—	—	,,

Distance du stigmate au bord du calice.—Fréquence relative pour 25 observations. Fig. 9 *bis*.

	+3	+2½	+2	+1½	+1	+½	0	−½	−1	−1½	−2	−2½	−3	−3½	−4	Millimètres
Grandes plantes (Table I, col. 5)	—	—	—	—	2	2	5	4	8	1	2	1	—	—	—	Nombre de plantes
Petites plantes (Table II, col. 5)	—	1	1	1	—	2	6	2	7	1	2	—	1	1	—	,,

Hauteur des étamines au-dessus de la base de la corolle.—Fréquence relative. Fig. 11.

	4	4½	5	5½	6	6½	7	7½	Millimètres
Grandes plantes (Table I, col. 6)	—	—	7	5	7	2	4	—	Nombre de plantes
Petites plantes (Table II, col. 6)	—	—	3	4	9	6	3	—	,,

Distance du stigmate à l'anthère.—Fréquence relative. Fig. 9.

	3	3½	4	4½	5	5½	6	6½	7	7½	Millimètres
Grandes plantes (Table I, col. 7)	—	1	3	4	6	6	3	2	—	—	Nombre de plantes
Petites plantes (Table II, col. 7)	—	—	3	2	7	5	6	2	—	—	,,

Nombre de fleurs par inflorescences.—Fréquence relative, pour 25 observations. Fig. 12.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
25 Grandes plantes (Table I, col. 8)	—	—	—	—	1	5	14	12	5	8	2	2	1	—	—	1	—	—	—	—	—	—	—	51 inflorescences
25 Petites plantes (Table II, col. 8)	—	2	1	2	—	2	9	15	6	7	2	1	—	—	—	—	—	—	—	1	—	—	—	48 inflorescences

Nombre de fleurs par individus.—Fréquence relative pour 25 observations. Fig. 7.

	2	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*
Grandes plantes (Table I, col. 8)	–	–	–	–	–	–	–	–	–	2	2	4	3	4	3	3	–	2	1	1	–	–	–	–	–	–	–	–	–
Petites plantes (Table II, col. 8	–	1	–	–	1	1	1	–	1	1	–	5	2	5	3	2	–	1	–	–	–	–	–	–	1	–	–	–	–

Voici les conclusions ou les observations qu'on peut retirer de la comparaison entre les dimensions des fleurs des 25 grandes plantes et celles des 25 petites plantes.

1. Pour les dimensions du style et du calice, chez les grandes plantes le type semble plus concentré autour de la valeur moyenne (valeur plus grande de σ chez les petites plantes; voyez la Table VI). Ainsi, pour un même nombre (25) d'échantillons de chaque sorte, c'est chez les petites plantes que nous avons rencontré, dans la localité considérée, les plus grands et les plus petits styles, les plus grands et les plus petits calices. Nous n'avons pas ici d'ailleurs la limite extrême possible de la variabilité, puisque cette limite recule naturellement lorsqu'on considère un nombre sans cesse croissant d'échantillons. Par la suite du travail on verra, en effet, que les limites supérieures de la longueur du style ont été enregistrées de la façon suivante :

Avec	50 observations	(Maxéville, 1903)	16·5 mm.
„	173 „	(Maxéville, 1902)	17 „
„	235 „	(Messein, 1903)	18 „
„	476 „	(Maxéville, 1903)	19 „

La chance de trouver un calice très long est d'autant plus petite que la longueur du calice devient plus grande. La rapidité avec laquelle diminue la chance de trouver un calice d'écart donné s'exprime par la valeur de la quantité σ.

TABLE VI.

Valeurs moyennes des caractères, étudiées dans les plantes de grande taille et dans celles de petite taille. (Valeurs en millimètres.)

Caractère	Grandes plantes			Petites plantes		
	Moyenne	σ	$\frac{\sigma}{\sqrt{N}}$	Moyenne	σ	$\frac{\sigma}{\sqrt{N}}$
Hauteur totale du calice	12·52	1·044	0·209	12·78	1·582	0·316
Hauteur du style au-dessus de l'ovaire ...	9·94	0·683	0·136	10·32	0·858	0·172
Distance du stigmate au bord du calice ...	−0·60	0·927	0·186	−0·52	1·345	0·269
Hauteur des étamines au-dessus de la base de la corolle	5·82	0·691	0·138	6·04	0·623	0·125
Distance du stigmate à l'anthère	5·10	0·707	0·141	5·30	0·683	0·137
Nombre de fleurs par inflorescence ...	7·41	1·981	0·277	7·08	2·730	0·394
Nombre de fleurs par individu	15·12	2·658	0·266	13·60	4·499	0·450

Si l'on se bornait à l'examen de cette Table VI. on pourrait, il est vrai, croire à une petite différence du type chez les grandes et chez les petites plantes.

On voit en effet que la valeur moyenne de longueur du style est de 9·94 mm. pour les grandes et 10·32 pour les petites: soit une différence de 0·38 mm. Mais ces valeurs sont sensiblement égales, et la différence apparaît négligeable, lorsqu'on voit la grande valeur de la quantité $\frac{\sigma}{\sqrt{N}}$ dans chaque série. On remarque ainsi que l'étude d'un nombre d'échantillons beaucoup plus grand rapprocherait vraisemblablement ces valeurs moyennes, calculées avec 25 échantillons seulement de chaque sorte.

Chez les petites plantes on rencontre les types de styles les plus inclus et les plus exsertes. Fig. 9 *bis* et Fig. 3.

Pourtant le type moyen semble être le même.

On trouve en effet pour 25 observations de chaque type:

	Grandes plantes	Petites plantes
Styles plus longs que le calice	4	5
Styles égaux au calice	5	6
Styles plus petits que le calice	16	14

Mais il en résulte que les petites plantes ont un style qui a, par rapport au calice, une capacité de croissance plus grande que chez les grandes plantes.

Dans les grandes comme dans les petites plantes il y a donc environ $\frac{3}{5}$ d'incluses, $\frac{1}{5}$ d'exsertes, et $\frac{1}{5}$ de types intermédiaires.

2. La distance du stigmate à l'anthère semble rester très constante comme on le voit, aussi bien au point de vue des valeurs extrêmes que de la longueur moyenne. Fig. 9 et Fig. 3.

Le type le plus fréquent est le type $5\frac{1}{4}$.

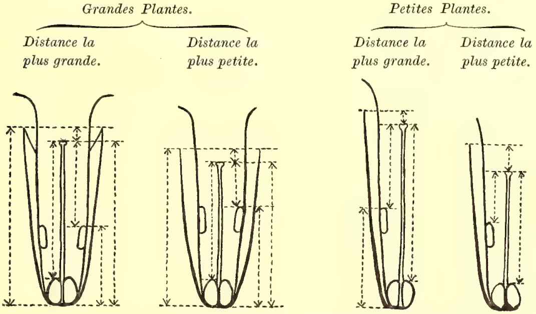
L'amplitude des variations constatées est de 4 à $6\frac{1}{2}$, soit 2·5 d'écart, c'est-à-dire de 1·25 au-dessus et au-dessous du type le plus fréquent.

La courbe ici semble être nettement symétrique.

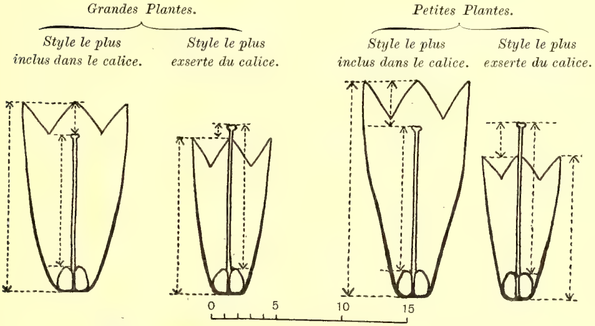
3. Les grandes plantes ont plus de fleurs que les petites:

25 grandes en ont 378, soit 15·1 par plante,
25 petites en ont 340, soit 13·6 par plante.
Différence 38, environ $\frac{1}{9}$ à $\frac{1}{10}$ en plus.

4. On voit de même que chez les petites plantes le nombre de fleurs par individus et par inflorescences est moins constant. C'est chez les petites plantes qu'on trouve les individus et les inflorescences à fleurs les plus nombreuses et les moins nombreuses. Il y a 6 à 7 fleurs par inflorescences et 13 à 15 par individus en général. Fig. 7.



Types extrêmes de distance entre l'anthère et le stigmate.


Grandes Plantes.
Petites Plantes.
Style le plus inclus dans le calice.
Style le plus exserte du calice.
Style le plus inclus dans le calice.
Style le plus exserte du calice.
0
5
10
15

Rapports de longueur entre le calice et le style. Millimètres.

FIG. 3. Types extrêmes des Tables I. et II.

En résumé, malgré les variations individuelles de taille qu'il est facile de rencontrer, *les types morphologiques des fleurs ne sont pas sensiblement modifiés par la plus ou moins grande vigueur de la végétation.* Nous pouvons constater des différences dans le nombre des fleurs plutôt que des différences dans les dimensions des fleurs et dans les dimensions relatives des parties.

II.

COMPARAISON ENTRE LES PLANTES BRÉVISTYLÉES ET LES PLANTES BRÉVISTÉMONÉES D'UNE LOCALITÉ. (Maxéville, 1903, et Messein, 1903.)

A Maxéville nous avons fait une récolte de 120 pieds de chaque sorte et nous avons pris au hasard, dans les deux lots, 25 échantillons de plantes dolichostylées et 25 échantillons de plantes brachystylées.

A Messein le nombre des plantes récoltées en une seule fois a été de 140 plantes brévistémonées et 95 plantes brévistylées. Les mensurations qui ont été plus nombreuses qu'à Maxéville (235 plantes au lieu de 50) sont relatives à trois caractères seulement. Elles avaient pour but de vérifier quelques unes des conclusions qu'on pouvait tirer à Maxéville d'un nombre de plantes plus restreint.

Indépendamment d'ailleurs des résultats mentionnés aux Tables Nos. VII et IX, toutes les tables suivantes donnent aussi un grand nombre d'indications sur la même question de comparaison.

On trouvera ci-après :

(1) La Table No. VII des mensurations, et le résumé des variations.

(2) La Table No. VIII des fréquences, tirées de la Table No. VII.

(3) Les graphiques exprimant les résultats de la Table No. VIII. Voyez Figs. 7, 12, et 13 à 18, p. 454.

(4) La Table No. IX et les graphiques qui s'y rapportent (Messein). Voyez Figs. 19—22, p. 455.

(5) Les variations comparées des fleurs brévistylées et brévistémonées.

(6) Des documents sur la fréquence relative des deux types et sur leur floraison comparée, avec statistiques et graphiques.

TABLE VII.

Comparaison entre les Plantes brévistylées et les Plantes brévistémonées d'une localité (Maxéville). (Année 1903.)

25 plantes de chaque sorte prises au hasard dans une récolte de 120 pieds. (Valeurs en millimètres.)

	Brévistémonées								Brévistylées							
Nos. des plantes	Hauteur du calice	Hauteur du stigmate au-dessus de la base du calice	Longueur du style au-dessus de l'ovaire	Distance du stigmate au bord du calice. Style		Distance du haut des étamines au-dessus de la base		Distance du haut du stigmate au sommet de l'anthère	Hauteur du calice	Hauteur du stigmate au-dessus de la base du calice	Longueur du style au-dessus de l'ovaire	Distance du stigmate au bord du calice	Distance de la base des anthères au-dessus de la base de		Distance du stigmate à la base de l'anthère	Distance du haut de l'anthère à la base du calice
				Inclus dans le calice	Exserte du calice	De la corolle	Du calice						La corolle	Du calice		
1	14	13	11	−1	—	7	8	5	14	7	5	7	10½	11½	4½	13½
2	13	13	11	—	—	7	8	5	12½	8	6	4½	10	11	3	13
3	14½	12	10	−2½	—	6½	7½	4½	14½	7	5	7½	10	11	4	13
4	16½	13½	11½	−3	—	7½	8½	5	12½	8	6	4½	9½	10½	2½	12½
5	13½	12	10	−1½	—	6½	7½	4½	14	7½	5½	6½	11	12	4½	14
6	14	12	10	−2	—	6	7	5	10½	7½	5½	3	7½	8½	1	10½
7	14	11½	9½	−2½	—	6½	7½	4	12	6	4	6	11	12	6	14
8	13½	11½	9½	−2	—	7	8	3½	11	7	5	4	10	11	4	13
9	12½	12	10	− ½	—	7	8	4	13	6½	4½	6½	10	11	4½	13
10	12	13	11	—	+1	7	8	5	13½	7	5	6½	9	10	3	13
11	15	13½	11½	−1½	—	8	9	4½	14	7	5	7	10	11	4	13
12	12	12½	10½	—	+½	6½	7½	5	12½	8	6	4½	10½	11½	3½	13½
13	15½	15	13	− ½	—	7	8	7	12½	7	5	5½	10	11	4	13
14	16½	14	12	−2½	—	7½	8½	5½	16	8	6	8	9½	10½	2½	12½
15	16	14½	12½	−1½	—	7½	8½	6	13	7	5	6	8½	9½	2½	11½
16	12½	11	9	−1½	—	7	8	3	11	7	5	4	7½	8½	1½	10½
17	14	12	10	−2	—	7½	8½	3½	13½	9½	7½	4	10	11	1½	13
18	14	14	12	−1	—	7	8	6	13	7	5	6	10	11	4	13
19	12½	11	9	—	—	6½	7½	3½	16	7	5	9	9½	10½	3½	12½
20	13	13½	11½	−1½	—	6½	7½	6	14½	7½	5½	7	8	9	1½	11
21	13½	12	10	− ½	—	7	8	4	14	7½	5½	6½	8½	9½	2	11½
22	13	13½	11½	−1½	—	6½	7½	6	14	9	7	5	11	12	3	14
23	15	13½	11½	− ½	—	7	8	5½	14	6½	4½	7½	8½	9½	3	11½
24	15	13½	11½	−1½	—	7½	8½	5	13	7	5	6	9	10	3	12
25	16	13½	11½	−2½	—	8	9	4½	14	7½	5½	6½	10	11	3½	13
Limites de la variation enregistrées avec 25 échantillons	12—16½	11—15	9—13	(−3) (+1)		6—8	7—9	3—7	10½—16	6—9½	4—7½	3—9	7½—11	8½—12	1—6	10½—14

TABLE VIII.

Résumant les fréquences de dimensions obtenues avec les plantes du Table VII.
Figs. 13—18.

Longueur en millimètres	Longueur du style		Distance du stigmate au bord du calice		Distance entre le haut de l'anthère et le haut du calice		Distance du stigmate à l'anthère		Hauteur des étamines au-dessus de la base de la corolle		Hauteur du calice	
	Brévistylées	Brévistémonées	Brévistylées	Brévistémonées	Brévistylées	Brévistémonées	Brévistylées	Brévistémonées	Brévistylées	Brévistémonées	Brévistylées	Brévistémonées
+3	—	—	—	—	—	—	—	—	—	—	—	—
+2½	—	—	—	—	—	—	—	—	—	—	—	—
+2	—	—	—	—	2	—	—	—	—	—	—	—
+1½	—	—	—	—	1	—	—	—	—	—	—	—
+1	—	—	—	1	1	—	—	—	—	—	—	—
+½	—	—	—	1	2	—	—	—	—	—	—	—
0	—	—	—	2	6	—	—	—	—	—	—	—
½	—	—	—	4	3	—	—	—	—	—	—	—
1	—	—	—	1	3	—	1	—	—	—	—	—
1½	—	—	—	8	2	—	3	—	—	—	—	—
2	—	—	—	3	—	—	1	—	—	—	—	—
2½	—	—	—	4	2	—	3	—	—	—	—	—
3	—	—	1	1	—	2	5	1	—	—	—	—
3½	—	—	—	—	3	1	3	3	—	—	—	—
4	1	—	3	—	—	1	5	3	—	—	—	—
4½	2	—	3	—	—	5	3	4	—	—	—	—
5	11	—	1	—	—	6	—	7	—	—	—	—
5½	5	—	1	—	—	2	—	2	—	—	—	—
6	4	—	4	—	—	3	1	4	—	1	—	—
6½	—	—	5	—	—	2	—	—	—	7	—	—
7	1	—	3	—	—	1	—	1	—	10	—	—
7½	1	—	2	—	—	1	—	—	—	5	—	—
8	—	—	1	—	—	—	—	—	—	2	—	—
8½	—	—	—	—	—	1	—	—	—	—	—	—
9	—	2	1	—	—	—	—	—	—	—	—	—
9½	—	2	—	—	—	—	—	—	2	—	—	—
10	—	6	—	—	—	—	—	—	1	—	—	—
10½	—	1	—	—	—	—	—	—	3	—	1	—
11	—	3	—	—	—	—	—	—	2	—	2	—
11½	—	7	—	—	—	—	—	—	3	—	—	—
12	—	2	—	—	—	—	—	—	9	—	1	2
12½	—	1	—	—	—	—	—	—	2	—	4	3
13	—	1	—	—	—	—	—	—	3	—	4	4
13½	—	—	—	—	—	—	—	—	—	—	2	3
14	—	—	—	—	—	—	—	—	—	—	7	4
14½	—	—	—	—	—	—	—	—	—	—	2	1
15	—	—	—	—	—	—	—	—	—	—	—	3
15½	—	—	—	—	—	—	—	—	—	—	—	1
16	—	—	—	—	—	—	—	—	—	—	2	2
16½	—	—	—	—	—	—	—	—	—	—	—	2

TABLE IX.

P. officinalis.—Messein, 1903. Figs. 19—23.

(Pour abréger nous ne donnons pas ici le tableau des *mensurations* détaillées, mais seulement le *tableau des fréquences* qui résume ces mensurations au nombre de plus de 900.)

Hauteur totale du calice.

Dimensions en mm.	*9*	*9½*	*10*	*10½*	*11*	*11½*	*12*	*12½*	*13*	*13½*	*14*	*14½*	*15*	*15½*	*16*	*16½*	*17*	*17½*	*18*	*18½*	
Brévistémonées ...	—	—	1	1	1	7	9	9	21	17	21	12	16	6	13	3	1	1	1	—	140 pl.
Brévistylées ...	—	—	1	1	2	4	8	7	10	12	12	12	17	4	3	2	—	—	—	—	95 pl.

Longueur du style.

	3	*3½*	*4*	*4½*	*5*	*5½*	*6*	*6½*	*7*	*7½*	*8*	*8½*	*9*	*9½*	*10*	*10½*	*11*	*11½*	*12*	*12½*	*13*	*13½*	*14*	*14½*	*15*	*15½*	*16*	
Brévistémonées ...	—	—	—	—	—	—	—	1	—	—	7	3	11	15	36	20	22	11	9	—	5	—	—	—	—	—	—	140 pl.
Brévistylées ...	—	1	6	16	41	26	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	95 pl.

Distance du stigmate à l'anthère.

	0	*½*	*1*	*1½*	*2*	*2½*	*3*	*3½*	*4*	*4½*	*5*	*5½*	*6*	*6½*	*7*	*7½*	*8*	*8½*	*9*	*9½*	*10*	
Brévistémonées ...	—	—	1	—	1	1	8	8	18	20	15	22	13	7	2	1	1	1	—	—	—	120 pl.
Brévistylées ...	—	—	—	—	3	10	14	20	17	7	3	—	—	—	—	—	—	—	—	—	—	74 pl.

Distance du stigmate au bord du calice.

	+4	*3½*	*3*	*2½*	*2*	*1½*	*1*	*½*	*0*	*−½*	*1*	*1½*	*2*	*2½*	*3*	*3½*	*4*	*4½*	*5*	*5½*	*6*	*6½*	*7*	*7½*	*8*	*8½*	*9*	*9½*	*10*	
Brévistémonées ...	—	1	—	—	1	1	3	7	11	19	22	18	23	14	11	6	9	2	—	1	—	1	—	—	—	—	—	—	—	150 pl.
Brévistylées ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	4	8	5	16	15	12	19	9	3	1	2	—	95 pl.

TABLE X.

Variations comparées des plantes brévistylées et brévistemonées (Maxéville et Messein).

Catégories		Maxéville 1903 (Résumé du Tableau VIII)		Messein 1903 (Résumé du Tableau IX)	
		Brévistylées 25 plantes	Brévistémonées 25 plantes	Brévistylées 95 plantes	Brévistémonées 120 à 150 plantes
Proportion centésimale de		anthères	styles	anthères	styles
	styles ou anthères exsertes du calice ...	24 p. 100	8 p. 100	—	9 p. 100
	styles ou anthères égaux au calice	24 „	8 „	—	8 „
	styles ou anthères inclus dans le calice ...	52 „	84 „	—	83 „
		millimètres	millimètres	millimètres	millimètres
Hauteur du calice* (chiffres extrêmes) enregistrés avec 25 échantillons ...		10½ à 16	12 à 16½	10 à 16½	10 à 18
Hauteur du stigmate au-dessus de la base du calice		6—9½	11—15	5½—8	8½—15
Longueur du style au-dessus de l'ovaire		4—7½	9—13	3½—6	6½—13
Hauteur du pistil au-dessus de la base du calice		6—9½	11—15	—	—
Distance du stigmate au bord du calice		3—9	+1 à −3	3½—9½	+3½ à −6½
Hauteur du haut des étamines au-dessus de la base du calice		10½—14	7½—9	—	—
Distance du stigmate à l'anthère ...		1—6	3—7	—	—
Nombre des fleurs par inflorescences ...		3 à 11	1 à 15	2 à 5	1 à 8½
Nombre moyen de fleurs par inflorescences		moyenne 7, 1	moyenne 6, 9		
Nombre de fleurs par individu ...		6 à 21	7 à 24		
Nombre de fleurs pour 1000 individus		13554	13573		
Nombre moyen de fleurs par individu		13, 55	13, 57		

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* Nous n'avons pas mesuré les dimensions des corolles. Elles sont d'ailleurs aussi très variables quant à la hauteur du tube de la corolle et quant aux dimensions des lames des pétales.

TABLE XI.

Comparaison entre les plantes de Maxéville (Table VIII.) *et celles de Messein* 1903 (Table IX.).

Caractère	Brévistémonées				Brévistylées			
	Maxéville		Messein		Maxéville		Messein	
	Moyenne	σ	Moyenne	σ	Moyenne	σ	Moyenne	σ
Longueur du style	10·82	1·057	10·29	1·142	5·36	0·742	5·03	0·499
Distance du stigmate à l'anthère ...	4·82	1·028	4·85	1·195	3·20	1·394	3·48	1·437
Distance du stigmate au bord du calice	1·30	0·707	1·58	1·472	5·94	1·424	6·68	1·158
Hauteur du calice	14·00	1·349	13·90	1·465	13·30	1·377	13·73	1·370
Hauteur des étamines au-dessus de la corolle	7·00	0·490	—	—	11·56	0·993	—	—
Distance entre le haut de l'anthère et le haut du calice	−5·23	1·314	—	—	−0·62	1·545	—	—

Chez les plantes brévistémonées il y a une ressemblance remarquable du type, dans les deux localités de Messein et Maxéville.

Messein	Maxéville	
83 par 100	84 par 100	de styles inclus
8 „	8 „	de styles affleurant au bord du calice
9 „	8 „	de styles exsertes.

S'on représente par l la longueur du style (Fig. 4), et par d la distance du stigmate au bord du calice, il existe trois types de plantes qui réalisent les rapports de longueur suivants: $l > d$, $l = d$, $l < d$.

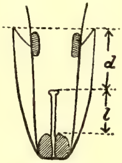


FIG. 4.

Chez les plantes brévistylées de Maxéville et de Messein les différences sont plus grandes :

Maxéville.	Messein.
68 p. 100 de styles $l < d$.	80 p. 100 de styles $l < d$.
0 „ „ $l = d$.	8 „ „ $l = d$.
32 „ „ $l > d$.	12 „ „ $l > d$.

En ce qui concerne la situation des anthères voici ce qu'on observe à Maxéville:

24 p. 100 d'anthères dépassent le calice. Calice à croissance limitée (très fréquent) ou corolle à croissance exagérée (plus rare).
24 „ „ effleurent le haut du calice.
52 , „ sont incluses dans le calice.

Pour compléter la comparaison des plantes brévistylées et des plantes brévistémonées voici quelques chiffres: (*a*) sur leur fréquence relative, (*b*) sur leur floraison dans deux autres localités présentant une différence dans la nature du sol.

a. *Fréquence du type* (p. 1000 plantes brévistylées):

	A Malzéville sur calcaire jurassique (moyenne 4 prises d'échantillons)	A Essey sur le Lias (1 prise d'échantillon)
Plantes brévistylées	1000	1000
Plantes brévistémonées	936	767

Les plantes brévistylées paraissent donc plus nombreuses d'environ $\frac{1}{10}$ à $\frac{1}{5}$. A Nancy il en serait de même pour *Primula grandiflora*. (D'après une de nos statistiques inédites.) Mais ce calcul présente une certaine incertitude puisqu'il est basé sur les observations d'une seule année.

b. *Floraison des Pulmonaires.*

Nombre des grappes florales par plante (par 100 plantes observées).

Catégories de plantes	1 grappe	2 grappes	3 grappes	Nombre total de grappes
Brévistémonées ...	3	92	5	202
Brévistylées ...	18	77	5	187

Nombre de fleurs par grappes des divers ordres (par 1000 plantes).

Chiffres calculés avec 40 à 50 plantes seulement de chaque type.

Inflorescences ayant un nombre de fleurs de	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	Totaux	
																	Inflorescence par 1000 plantes	Fleurs pour 1000 plantes
Nombre de grappes des plantes brévistémonées	—	—	55	138	193	416	610	138	249	57	110	—	—	—	—	—	1966	13573
Nombre des grappes brévistylées ...	91	22	—	91	182	320	523	136	182	91	136	68	22	—	22	—	1886	13554

Nombre de fleurs de la grappe terminale (par 1000 plantes).

Nombre des fleurs	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	Nombre moyen par grappe terminale
Nombre des plantes brévistémonées	—	—	55	361	388	55	55	53	33	—	—	—	6·98
Nombre des plantes brévistylées ...	—	22	68	204	408	44	113	47	28	44	22	—	7·46

Les trois tableaux précédents montrent bien qu'il ne semble pas y avoir entre les deux types d'autres particularités que celle-ci :

Les plantes brévistémonées donnent un plus grand nombre d'inflorescences que les brévistylées et le nombre des fleurs n'est pas très différent dans les deux cas.

Mais cette conclusion est-elle générale ? Nous avons cru devoir faire une autre statistique relative au nombre des fleurs afin de voir si la conclusion différente obtenue par Hildebrand ne se trouvait jamais justifiée.

Voici la table de fréquence et le graphique, Fig. 5, relatif à une prise de 33 pieds, isolés de 3 mètres, récoltés à Maxéville en 1903. (Plantes du 4^e lot, Table XII.)

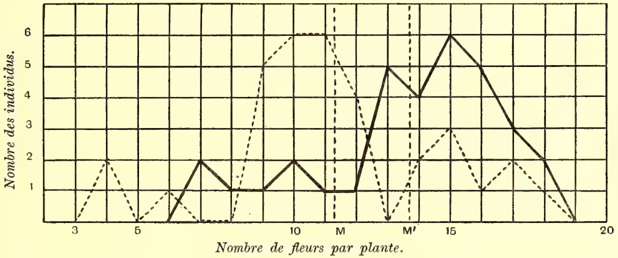


FIG. 5. Nombre de fleurs par plante.

Brévistylées ———— M = Nombre moyen pour les Brévistémonées.
Brévistémonées - - - - - M' = ,, ,, ,, Brévistylées.

Nombre des fleurs par individu.

Nombre des fleurs	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	Nombre total	Nombre moyen
Nombre des individus 33 plantes brévistémonées	–	–	2	–	1	–	–	5	6	6	4	–	2	3	1	2	1	–	374	11·3
,, brévistylées ...	–	–	–	–	–	2	1	1	2	1	1	5	4	6	5	3	2	–	452	13·7

Ce résultat pourrait sembler confirmer celui qu'a obtenu Hildebrand avec 10 plantes seulement de chaque sorte. Il y a environ 20 $^{\circ}/_{\circ}$ de fleurs en plus chez les Brévistylées récoltées dans cette localité des environs de Nancy. (Hildebrand avait trouvé 29 $^{\circ}/_{\circ}$ pour celles qu'il avait observées en Allemagne.) D'autre part, dans une localité voisine de celle qui nous venons d'étudier, à Maxéville même, nous avions trouvé un résultat très différent; 13·5 *fleurs par plante, pour chacun des deux types brévistylés et brévistémonés.* (Voyez Fig. 7, et page 422 : 13554 fleurs brévistylées et 13573 fleurs brévistémonées pour 1000 plantes de chaque sorte.) Nous pensons donc qu'il n'y a pas lieu d'admettre, comme une règle, que les plantes brévistylées sont plus riches en fleurs que les plantes brévistémonées. Il est comme on le voit possible de trouver des localités où il en est tout autrement. D'ailleurs nous avons démontré plus haut que *le nombre des fleurs dépend* *en partie de la vigueur des plantes,* puisque chez les plantes brévistémonées de grande taille le nombre moyen de fleurs par pied peut passer de 13·6 à 15·12, et même plus, lorsqu'on s'adresse successivement à des plantes de taille de plus en plus grande. Définitivement nous concluons donc tout autrement que ne l'a fait Hildebrand. Cet auteur ne disposait que d'un trop petit nombre d'échantillons, et ses conclusions ne pouvaient être que très approximatives avec 10 plantes seulement de chaque sorte. Il admettait donc, à tort croyons-nous, et avec lui Darwin aussi, que l'hétérostylie donne deux types d'inégale floraison et que les plantes brévistylées produisent plus de fleurs.

Pour nous il n'en est rien : *Les deux types brévistylés et brévistémonés produisent, dans la région de Nancy, un nombre de fleurs variable, en rapport avec les conditions de végétation, mais non dépendant de l'hétérostylie.* Le chiffre moyen est de 13 à 14 fleurs par plante et nous nous demandons comment Hildebrand a pu donner un chiffre moyen de 28·9 pour les Brévistémonées et 38·7 pour les Brévistylées. S'il n'y a pas d'erreur d'impression dans le mémoire, cet auteur aurait étudié un type de Pulmonaire officinale très différent pour la floraison de celui qui se trouve en Lorraine.

III.

ÉTUDE COMPARÉE DES PLANTES RÉCOLTÉES DEUX ANNÉES DE SUITE, À 5 REPRISES DIFFÉRENTES, DANS DES LOCALITÉS VOISINES (MAXÉVILLE), ANNÉES 1902 ET 1903.

En 1903, les 4 lots comprenaient au total 238 plantes de chaque sorte, ce qui correspond à 1904 mesures différentes.

Nous avons pensé qu'il n'était pas urgent de donner un tableau général des 1904 mesures; comme nous l'avons fait précédemment pour la récolte de Messein, nous donnons seulement les tableaux de fréquence qui résument ces mesures.

Néanmoins il nous a paru intéressant de donner les graphiques correspondant à chacun des lots, avant de donner les graphiques qui sont tracés avec les chiffres totaux.

En 1902 le lot unique comprend 138 plantes brévistémonées et 35 brévistylées; leurs mesures ont été données.

On trouvera donc ci-après :

A. Table XII résumant les fréquences pour chacun des 4 lots de 100, 80, 25, 33 plantes; et donnant les nombres totaux pour l'ensemble des 238 plantes récoltées à Maxéville en 1903.

B. Graphiques des lots 1, 2, 3, 4. Voyez Figs. 23—36 et 13—18.

C. Graphiques exprimant les résultats pour l'ensemble des 4 lots précédents (1903). Voyez Figs. 53—56.

D. Tables XIII et XIV *c*, des mensurations de 138 plantes brévistémonées et des 35 plantes brévistylées récoltées en 1902 dans le même endroit.

E. Tables XIV*a* et XIV*b* de comparaison des plantes de 1902 et 1903.

F. Graphiques donnant la comparaison des plantes de 1902 et 1903. Voyez Figs. 61—63 et Figs. 53—56.

A.

TABLE XII.

Maxéville, 4 prises différentes (1903), *localités voisines.*

Hauteur totale du calice. Figs. 23, 28, 18, 33.

Nombre de millimètres	*8*	*8½*	*9*	*9½*	*10*	*10½*	*11*	*11½*	*12*	*12½*	*13*	*13½*	*14*	*14½*	*15*	*15½*	*16*	*16½*	*17*	*17½*	*18*	*18½*	*19*	*19½*	Plantes
1er lot, Brévistémonées	—	—	—	—	1	3	8	8	18	6	19	7	11	6	7	4	1	1	—	—	—	—	—	—	100
2e ,, ,,	—	—	—	—	—	2	4	6	13	18	8	12	13	3	—	—	1	—	—	—	—	—	—	—	80
3e ,, ,,	—	—	—	—	—	—	—	—	2	3	4	3	4	1	3	1	2	2	—	—	—	—	—	—	25
4e ,, ,,	—	—	—	—	—	1	—	1	3	2	4	4	9	1	4	3	—	—	—	—	—	—	1	—	33*
Nombre total	—	—	—	—	1	6	12	15	36	29	35	26	37	11	14	8	4	3	—	—	—	—	1	—	238

Nombre de millimètres	*8*	*8½*	*9*	*9½*	*10*	*10½*	*11*	*11½*	*12*	*12½*	*13*	*13½*	*14*	*14½*	*15*	*15½*	*16*	*16½*	*17*	*17½*	*18*	*18½*	*19*	*19½*	Plantes
1er lot, Brévistylées ...	—	1	—	1	—	1	9	10	15	4	11	10	20	6	5	—	4	1	1	1	—	—	—	—	100
2e ,, ,,	—	—	—	—	1	5	6	8	11	10	15	7	11	1	3	1	1	—	—	—	—	—	—	—	80
3e ,, ,,	—	—	—	—	—	1	2	—	1	4	4	2	7	2	—	—	2	—	—	—	—	—	—	—	25
4e ,, ,,	—	—	—	—	—	—	—	3	4	5	2	3	5	3	4	—	3	—	1	—	—	—	—	—	33
Nombre total	—	1	—	1	1	7	17	21	31	23	32	22	43	12	12	1	10	1	2	1	—	—	—	—	238

* Plantes isolées de 3 mètres au moins.

Hauteur du style au-dessus de l'ovaire. Figs. 24, 30, 16, 36.

Nombre de millimètres	*2½*	*3*	*3½*	*4*	*4½*	*5*	*5½*	*6*	*6½*	*7*	*7½*	*8*	*8½*	*9*	*9½*	*10*	*10½*	*11*	*11½*	*12*	*12½*	*13*	*13½*	*14*	Plantes
1er lot, Brévistémonées	—	—	—	—	—	—	—	—	—	—	—	3	6	12	18	31	6	9	4	9	2	—	—	—	100
2e ,, ,,	—	—	—	—	—	—	—	—	—	—	—	1	8	11	14	16	14	9	3	3	—	1	—	—	80
3e ,, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	6	1	3	7	2	1	1	—	—	25
4e ,, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	11	5	5	1	5	3	1	—	—	33
Nombre total	—	—	—	—	—	—	—	—	—	—	—	4	14	26	35	64	26	26	15	19	6	3	—	—	238

Nombre de millimètres	*2½*	*3*	*3½*	*4*	*4½*	*5*	*5½*	*6*	*6½*	*7*	*7½*	*8*	*8½*	*9*	*9½*	*10*	*10½*	*11*	*11½*	*12*	*12½*	*13*	*13½*	*14*	Plantes
1er lot, Brévistylées ...	—	—	3	17	20	37	7	14	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	100
2e ,, ,,	—	1	—	12	21	35	8	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	80
3e ,, ,,	—	—	—	1	2	11	5	4	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	25
4e ,, ,,	—	—	—	—	2	13	8	5	3	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	33
Nombre total	—	1	3	30	45	96	28	26	5	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	238

TABLE XII.—(*continued*).

Distance du stigmate à l'anthère. Figs. 25, 29, 14, 34.

Nombre de millimètres	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	Plantes
1^er lot, Brévistémonées	—	—	—	—	3	3	8	15	20	25	10	8	7	1	—	—	—	—	100
2^e ,, ,,	—	—	—	1	2	5	9	7	19	17	8	5	3	3	1	—	—	—	80
3^e ,, ,,	—	—	—	—	—	1	3	3	4	7	2	4	—	1	—	—	—	—	25
4^e ,, ,,	—	—	—	—	—	—	1	4	8	5	8	—	3	3	1	—	—	—	33
Nombre total	—	—	—	1	5	9	21	29	51	54	28	17	13	8	2	—	—	—	238

Nombre de millimètres	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	Plantes
1^er lot, Brévistylées ...	—	1	4	5	9	18	18	20	9	8	5	3	—	—	—	—	—	—	100
2^e ,, ,,	—	—	—	1	4	8	13	18	17	11	4	3	—	1	—	—	—	—	80
3^e ,, ,,	—	1	3	1	3	5	3	5	3	—	—	1	—	—	—	—	—	—	25
4^e ,, ,,	—	—	—	1	—	3	6	9	6	3	3	1	1	—	—	—	—	—	33
Nombre total	—	2	7	8	16	34	40	52	35	22	12	8	1	1	—	—	—	—	238

Distance du stigmate au bord du calice. Figs. 26, 31, 17, 35.

Nombre de millimètres	0	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	Plantes
1^er lot, Brévistylées ...	1	—	—	—	—	—	2	1	4	8	9	13	12	12	13	8	9	3	2	2	—	—	1	—	100
2^e ,, ,,	—	—	—	—	—	—	1	—	5	6	14	13	17	6	9	4	2	1	2	—	—	—	—	—	80
3^e ,, ,,	—	—	—	—	—	—	1	—	3	3	1	1	4	5	3	2	1	—	1	—	—	—	—	—	25
4^e ,, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nombre total	1	—	—	—	—	—	4	1	12	17	24	27	33	23	25	14	12	4	5	2	—	—	1	—	205

Nombre de millimètres	+2½	+2	+1½	+1	+½	0	−½	1	1½	2	2½	3	3½	4	4½	5	Plantes
1^er lot, Brévistémonées	—	2	5	4	5	14	12	14	17	15	5	4	2	1	—	—	100
2^e ,, ,,	—	1	2	5	3	12	15	16	9	14	2	1	—	—	—	—	80
3^e ,, ,,	—	—	—	1	1	2	4	1	8	3	4	1	—	—	—	—	25
4^e ,, ,,	—	—	1	2	2	3	5	7	4	6	2	—	—	1	—	—	33
Nombre total	—	3	8	12	11	31	36	38	38	38	13	6	2	2	—	—	238

Maxéville, 1903. *Longueur relative du style par rapport au calice (Brévistémonées). Proportion par cent.*

	De styles inclus	De styles égaux au calice	De styles exsertes
1^{er} lot (lot total 100) ...	70	14	15
2^e lot (lot total 80)	71	15	14
3^e lot (25 plantes, parmi 120)	84	8	8
4^e lot (100 pieds isolés de 3^m)	75	10	15
Moyennes des 4 chiffres	75	12	13

Longueur du style par rapport au calice (Brévistylées). Proportion par cent.

	Longueur du style plus grande que la distance au bord du calice $l > d$	Égale à la distance $l = d$	Longueur du style plus petite que la distance au bord du calice $l < d$
1^{er} lot	17 par 100	13 par 100	70 par 100
2^e lot	10 „	13 „	76 „
3^e lot	32 „	— „	68 „
4^e lot (pieds isolés de 3^m)	36 „	15 „	49 „
Moyennes des 4 chiffres	24	10	66

D.

TABLE XIII.

Maxéville (1902). *Plantes brévistémonées* (138 *plantes*).

Brévistémonées (138 plantes)												Brévistylées (35 plantes)		
Longueur du style	Hauteur totale du calice	Distance du calice au bord du stigmate	L	H	D	L	H	D	L	H	D	Longueur du style	Hauteur totale du calice	Distance du stigmate au bord du calice
11	14	−1	10	15	−3	9	14	−3	11	14½	−1½	5	14	7
11	10	+3	11½	14½	−1	9½	13½	−2	10	13	−1	5	16	9
11	15	−2	10	13	−1	9	11½	−½	12½	15	−½	5	13	6
11	14	−1	10½	13½	−1	9½	14	−2½	11	12	+1	4½	14	7½
9	11	—	11	15	−2	11½	14½	−1	10½	13	−½	5	12½	5½
9	15	−4	9	12½	−1½	12½	13½	+1	11	12½	+½	5	15	8
9	12	−1	10	13	−1	10½	13	−½	12	16	−2	4	15	9
11	15	−2	10	13	−1	11½	16	−2½	12	15	−1	6	14	6
10	14	−2	10	13	−1	10½	13	−½	10	14	−2	5½	15½	8
12	17	−3	12	16	−2	9	13	−2	11	15	−1	4	14	8
12	14	—	11½	13½	—	11	15	−2	10	13½	−½	5½	13½	6
10	16	−2	11	13	—	12	16	−2	10	13	−1	5	14	7
11½	13½	—	10	14	−2	9	13½	−1½	10	14	−2	5	13	6
10	13	−1	9½	15	−3½	12	16	−2	10½	11½	+1	5	13½	6½
8½	13	−2½	10	13	−1	10	13	−1	9½	13	−1½	5	14	7
11	14	−1	9½	11½	—	10	13	−1	10½	12½	—	5	13	6
9	14	−3	12	17	+3	11	13	—	11	12½	+½	5	13	6
10	13	−1	11½	13½	—	9	13	−2	9½	13½	−2	5	14	7
11	14½	−1½	10½	14	−1½	11½	14½	−1	8½	12	−1½	5	14	7
9½	14	−2½	12½	14½	—	9	14	−3	10½	17	−4½	5	12½	5½
11	13	—	11½	14	−½	11	13½	−½	11	13	−1	6	15½	7½
10	14	−2	9	12½	−1½	10	13	−1	9	13	−2	6	14	6
11	13	—	11	13	—	11	12	+1	9	13	−2	4	12	6
10	11½	+½	11	15	−2	12	13½	+½	9½	13½	−2	5½	13½	6
10½	12	+1	9	17½	−2½	10	14	−2	10	12	—	5	13½	6½
8	14	−4	10	14	−2	10	13½	−1½	10½	13½	−1	4	13½	7½
10	13	−1	11½	14½	−1	11½	12	+½	8½	10½	—	5½	13½	6
12	12	+2	9½	13½	−2	10	13	−1	11½	13	+½	5	14	7
9	12	−1	10	11½	+½	12	16	−2½	8½	10	+½	6	14	6
10	12	—	11½	15½	−2	9	15	−4	8½	12	−1½	5	13	6
10	12½	−½	10	13½	−1½	11	15	−2	8½	15	−4½	4½	15	8½
11	17	−4	11	14	−1	11	13	—	8	12	−2	6	14½	6½
10½	16	−3½	9½	14½	−3	9	15	−4	10	12	—	5	15	8
11	14	−1	10½	13	−½	10	15	−3	10	13	−1	5	13	6
11½	16	−2½	12½	13½	+1							5½	14	6½
			Amplitude de la variation					…	8 à 12½	10 à 17	+3 à −4½	4—6	12—16	5½—9

Chez les plantes brévistémonées il y a

76 p. 100 de styles inclus.
14 „ de styles égaux au calice.
10 „ de styles exsertes.

Nous plaçant au point de vue des renseignements botaniques faciles à vérifier, nous donnons ci-dessous quelques unes des dimensions observées. Elles peuvent être retenues au point de vue de la botanique descriptive et comparative des Pulmonaires de stations différentes.

E. TABLE XIV*a*.

Comparaisons des plantes de 1902, *et des plantes de* 1903, *d'une même localité* (*Maxéville*).

		Maxéville	
		Année 1902	Année 1903
		Brévistémonées (1902)	Brévistémonées (1903)
Proportion centésimale	styles exsertes du calice	10 par 100	13 par 100
	„ égaux au calice	14 „	12 „
	„ inclus dans le calice	76 „	75 „
Hauteur du calice	chiffres extrêmes enregistrés sur les échantillons observés	10 à 17 mm.	10 à 19 mm.
	chiffre de grande fréquence	13 „	13 ou 14 „
Hauteur du stigmate au-dessus de la base du calice		„ „	10 à 15 „
Longueur du style au-dessus de l'ovaire	chiffres extrêmes observés	8—12½ „	8—13 „
	chiffre de grande fréquence	10 „	10 „
Distance du stigmate au bord du calice	chiffres extrêmes	+3 à −4½ „	+2 à −4 „
	chiffre de grande fréquence	−1 „	−1 à −2 „
Distance du stigmate à l'anthère	chiffres extrêmes observés	„ „	2—7½ „
	chiffre de grande fréquence	„ „	4½ ou 5 „
		Brévistylées (1902)	Brévistylées (1903)
Hauteur du calice	chiffres extrêmes observés	12 à 16 mm.	8½ à 17½ mm.
	chiffre de grande fréquence	14 „	14 „
Hauteur du stigmate au-dessus de la base du calice		„ „	5 à 9½ „
Longueur du style au-dessus de l'ovaire	chiffres extrêmes observés	4—6 „	3—7½ „
	chiffre de grande fréquence	5 „	5 „
Distance du stigmate au bord du calice	chiffres extrêmes observés	−5½ à −9 „	0 à −11 „
	chiffre de grande fréquence	−6 „	−6 „
Distance du stigmate à l'anthère	chiffres extrêmes observés	„ „	1 à 7 „
	chiffre de grande fréquence	„ „	4 „

Les chiffres ci-dessous offrent un intérêt plus considérable au point de vue de l'étude mathématique de la variation :

TABLE XIV*b*.

Maxéville 1902 *et* 1903.

	Brévistémonées				Brévistylées			
	1902		1903		1902		1903	
	Moyen	σ	Moyen	σ	Moyen	σ	Moyen	σ
Hauteur totale du calice	13·62	1·369	13·12	1·377	13·87	0·897	13·04	1·474
Hauteur du style	10·37	1·029	10·21	1·081	5·07	0·549	4·99	0·700
Distance du stigmate à l'anthère ...	—	—	—	—	—	—	3·84	1·070
Distance du stigmate au bord de la calice	−1·26	1·305	−0·92	1·159	6·80	0·920	6·05	1·439

F. *P. officinalis, Maxéville,* 1902. *Table XIV c. obtenu avec les chiffres mentionnés à la Table XIII.*

Hauteur totale du calice. Fig. 63.

Dimensions en mm.	*9*	*9½*	*10*	*10½*	*11*	*11½*	*12*	*12½*	*13*	*13½*	*14*	*14½*	*15*	*15½*	*16*	*16½*	*17*	*17½*	*18*	*18½*	*19*	Plantes
Brévistémonées ...	—	—	2	1	1	5	13	6	32	19	22	7	16	1	9	—	4	—	—	—	—	138
Brévistylées ...	—	—	—	—	—	—	1	2	6	6	12	1	4	2	1	—	—	—	—	—	—	35

Longueur du style. Fig. 62.

Dimensions en mm.	*3*	*3½*	*4*	*4½*	*5*	*5½*	*6*	*6½*	*7*	*7½*	*8*	*8½*	*9*	*9½*	*10*	*10½*	*11*	*11½*	*12*	*12½*	*13*	*13½*	Plantes
Brévistémonées ...	—	—	—	—	—	—	—	—	—	—	2	5	18	10	34	13	28	13	11	4	—	—	138
Brévistylées ...	—	—	4	2	19	5	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	35

Distance du stigmate au bord du calice. Fig. 61.

Dimensions en mm.	+3½	*3*	*2½*	*2*	*1½*	*1*	+½	*0*	−½	−*1*	*1½*	*2*	*2½*	*3*	*3½*	*4*	*4½*	*5*	*5½*	*6*	*6½*	*7*	*7½*	*8*	*8½*	*9*	*9½*	Plantes
Brévistémonées ...	–	1	–	1	–	5	8	18	10	31	12	28	7	8	2	5	2	–	–	–	–	–	–	–	–	–	–	138
Brévistylées ...	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	13	4	6	3	4	1	2	–	35

Chez les plantes brévistémonées il y a

76 par 100 de styles inclus.
14 „ de styles égaux au calice.
10 „ de styles exsertes.

Conclusions relatives à la fixité du type pendant deux années successives.

On voit en comparant les graphiques (Figs. 53—56 et Figs. 61—63) que les résultats sont très semblables pour les deux années 1902 et 1903 :

C'est ainsi que le maximum de fréquence de la longueur des deux styles est sur les chiffres 5 et 10 dans les deux cas, et malgré le nombre faible des observations faites.

La position relative des deux courbes pour la distance du stigmate à l'anthère est la même en 1902 pour tous les lots.

Il en est de même pour la position des 2 maxima de fréquence de la distance du stigmate au bord du calice : ils sont en 1902 et 1903 sur – 1 chez les Brévistémonées et + 6 chez les Brévistylées.

Le maximum des fréquences de la hauteur du calice est aussi dans tous les cas aux environs de 13 à 14.

On voit donc que l'influence du climat de l'année ne semble pas modifier les capacités de croissance des diverses parties de la fleur hétérostylée.

IV.

ÉTUDE COMPARÉE DES PLANTES DE QUATRE STATIONS DIFFÉRENTES DES ENVIRONS DE NANCY.

Nous avons récolté des plantes espacées de 3 mètres environ, afin de ne mesurer que des pieds issus de graines différentes.

Le nombre des plantes mesurées a été de 25 au moins pour chacune des stations de

Laxou, Malzéville, Maxéville, Messein.

Voici la série des documents mentionnés ci-après :

G. Tables XV, XVI, XVII, XVIII, donnant les mensurations des plantes de chacune des quatre localités.

H. Tables XIX, XX, XXI, XXII. Fréquences relatives des diverses longueurs étudiées.

I. Tables XXIII A et XXIII B. Variabilité comparative dans les quatre stations.

J. Schémas représentant les types extrêmes ou caractéristiques de chaque station. Voyez p. 451.

K. Graphiques comparés, relatifs aux Tables XIX, XX, XXI, XXII. Voyez Figs. 37—48, Figs. 49—52, et Figs. 57—60, pp. 457—8.

L. Des documents précédents nous pouvons conclure ensuite sur

Les caractères généraux des races géographiques observées,
Les types moyens théoriques calculés,
La variabilité et la fixité de l'hétérostylie chez la Pulmonaire.

G. TABLEAUX DES MENSURATIONS DES PLANTES DE QUATRE LOCALITÉS DIFFÉRENTES.

TABLE XV.

Pulmonaires récoltées à Laxou. (*Année* 1903.)

Les pieds récoltés étaient situés à 3 mètres de distance au moins. Valeurs en millimètres.

Brévistylées								Brêvistémonées						
Nos. des plantes	Nos. des dessins schématiques	Hauteur de l'étamine	Distance de l'anthère à la base du calice	Distance du haut du stigmate à la base de l'anthère	Longueur du style et du stigmate réunis	Hauteur totale du calice	Distance du stigmate au bord du calice	Nos. des plantes	Nos. des dessins schématiques	Hauteur de l'étamine	Distance du haut du stigmate à la partie supérieure de l'anthère	Longueur du style et du stigmate	Hauteur totale du calice	Distance du stigmate au bord du calice
1	—	12	10	3½	4½	15	8½	*1*	—	7½	2½	8	13½	-3½
2	—	11	9	3	4	11½	5½	*2*	—	7½	3	8½	14½	-4
3	—	11½	9½	3	4½	15	8½	*3*	—	7	4½	9½	14½	-3
4	4	10½	8½	2½	4	13	7	*4*	—	7½	3	8½	13½	-3
5	10–14	14	12	5	5	16½	9½	*5*	—	7	3½	8½	13½	-3
6	—	12	10	3½	4½	14½	8	*6*	2 bis & 7	8	1½	7½	14½	-5
7	—	10½	8½	2½	4	12	6	*7*	—	7	4	9	13½	-2½
8	—	12	10	4	4	12	6	*8*	—	6½	3½	8	14½	-4½
9	—	11½	9½	3½	4	12½	6½	*9*	—	6½	4½	9	14	-3
10	—	11½	9½	2½	5	13½	6½	*10*	—	6	3½	8½	14	-3½
11	—	12	10	3	5	16	9	*11*	—	6½	3½	8	12	-2
12	—	10½	8½	2½	4	13	7	*12*	—	7	4	9	13	-2
13	—	10½	8½	2½	4	13	7	*13*	—	6½	4½	9	13½	-2½
14	—	11½	9½	3	4½	15	8½	*14*	2—13	6½	3	7½	10½	-1
15	—	11	9	2	5	14	7	*15*	8	6	6	10	15	-3
16	—	11	9	2½	4½	14	7½	*16*	—	8	2	8	14½	-4½
17	9	11½	9½	1½	6	15½	7½	*17*	—	8	2	8	14½	-4½
18	—	11½	9½	3½	4	14	8	*18*	—	7	4	9	13	-2
19	—	11	9	2½	4½	13	6½	*19*	—	7½	4	9½	14½	-3
20	—	11½	9½	3	4½	13	6½	*20*	—	7	4	9	14	-3
21	—	11	9	2	5	16	9	*21*	—	7	3½	8½	14	-3½
22	—	11	9	1½	5½	13	5½	*22*	—	7½	3	8½	12½	-2
23	—	11	9	2	5	12	5	*23*	—	7	4½	9½	13	-1½
24	3	13	11	3	6	15	7	*24*	—	8	3½	9½	13	-1½
25	—	12½	10½	3½	5	14½	7½	*25*	—	7	4	9	14½	-3½
								26	—	7½	4½	9	13	-2
								27	1	7½	5	10½	13½	-1
								28	11	7½	3½	9	17	-6
								29	—	7	3½	8½	13	-2½
								30	—	6½	5	9½	13½	-2
								31	—	7½	3	8½	14	-3½
Valeurs extrêmes		10½–14	8½–12	1½–5	4–6	11½–16½	5–9	Valeurs extrêmes		6–8	1½–6	7½–10½	10½–17	-6 à -1

TABLE XVI.

Pulmonaires récoltées à Malzéville. (*Année* 1903.)

Les pieds récoltés étaient situés à 3 mètres de distance au moins dans une station regardant le midi.

Longueurs exprimées en millimètres.

Brévistylées								Brévistémonées						
Nos. des plantes	Nos. des dessins schématiques	Hauteur de l'étamine	Distance de l'anthère à la base du calice	Distance du haut du stigmate à la base de l'anthère	Longueur du style et du stigmate réunis	Hauteur totale du calice	Distance du stigmate au bord du calice	Nos. des plantes	Nos. des dessins schématiques	Hauteur de l'étamine	Distance du haut du stigmate à la partie supérieure de l'anthère	Longueur du style et du stigmate	Hauteur totale du calice	Distance du stigmate au bord du calice
1	—	12	10	3½	4½	11	4½	*1*	—	6½	4½	9	14	− 3
2	—	13	11	4	5	13	6	*2*	—	6½	5½	10	12	—
3	19	12	10	2	6	14	6	*3*	—	7½	4	9½	13	− 1½
4	—	13	11	4	5	13	6	*4*	—	7½	5	10½	14	− 1½
5	—	13	11	4	5	13	6	*5*	—	7	5	10	12½	− ½
6	—	11½	9½	3	4½	11½	5	*6*	—	6½	3½	8	12	− 2
7	—	12	10	3½	4½	11½	5	*7*	17	7	6	11	13	—
8	—	12	10	3½	4½	12	5½	*8*	—	7½	5½	11	14½	− 1½
9	20—30	12½	10½	4½	4	15	9	*9*	—	7½	4½	10	14	− 2
10	—	13	11	3	6	11½	3½	*10*	—	6½	5	9½	12	− ½
11	—	11	9	2½	4½	8	1½	*11*	18	6	3½	7½	10½	− 1
12	—	11½	9½	3½	4	10	4	*12*	—	7½	4	9½	12½	− 1
13	—	12½	10½	3½	5	11	4	*13*	29	6½	4½	9	10½	+ ½
14	—	11½	9½	2	5½	13	6½	*14*	—	8½	3½	10	12	—
15	—	11½	9½	3	4½	11½	5	*15*	—	7½	4½	10	13	− 1
16	—	12	10	3	5	12	5	*16*	24	6	7	11	13½	− ½
17	—	12	10	3	5	12½	5½	*17*	—	7	3½	8½	13	− 2½
18	25	12	10	2	6	12½	4½	*18*	—	6½	5	9½	11½	—
19	—	12	10	3½	4½	12½	6	*19*	—	6½	3½	8	11½	− 1½
20	—	11	9	2	5	11	4	*20*	—	8	4	10	12	—
21	—	12	10	3	5	12	5	*21*	27	7	4½	9½	14½	− 3
22	—	11½	9½	3	4½	13½	7	*22*	23	7	3	8	12	− 2
23	—	13	11	4½	4½	12½	6	*23*	—	7½	4½	10	14	− 2
24	—	13	11	5	4	13	7	*24*	—	6	4	8	12	− 2
25	—	12½	10½	4	4½	12	5½	*25*	—	7	6	11	12½	+ ½
Valeurs extrêmes		11–13	9–11	2–5	4–6	8–15	1½–9	Valeurs extrêmes		6–8½	3–7	7½-11	10½–14½	− 3 à + ½

TABLE XVII.

Pulmonaires récoltées à Maxéville. (*Année* 1903.)

(Les pieds récoltés étaient situés à 3 mètres de distance au moins dans une station regardant le nord.)

Longueurs exprimées en millimètres.

Brévistylées								Brévistémonées						
Nos. des plantes	Nos. des dessins schématiques	Hauteur de l'étamine	Distance de l'anthère à la base du calice	Distance du haut du stigmate à la base de l'anthère	Longueur du style et du stigmate. Hauteur du sommet du stigmate au-dessus de l'ovaire	Hauteur totale du calice	Distance du stigmate au bord du calice	Nos. des plantes	Nos. des dessins schématiques	Hauteur de l'étamine	Distance du haut du stigmate à la partie supérieure de l'anthère	Longueur du style et du stigmate	Hauteur totale du calice	Distance du stigmate au bord du calice
1	64	11	9	3	4	9½	3½	*1*	—	6½	5	9½	11	+½
2	—	11½	9½	2½	5	13	6	*2*	—	7	4½	9½	11	+½
3	—	10½	8½	2	4½	13	6½	*3*	—	5½	5	8½	12	−1½
4	—	12½	10½	3½	5	12½	5½	*4*	50	7	3½	8½	14	−3½
5	—	11	9	2½	4½	11½	5	*5*	—	7	3½	8½	12	−1½
6	—	12	10	3	5	13	6	*6*	49 & 56	7½	6½	12	14	—
7	—	12	10	2½	5½	12	4½	*7*	—	7	3½	8½	12	−1½
8	—	11½	9½	2½	5	12	5	*8*	—	6	5	9	11½	−½
9	—	12½	10½	4½	4	12½	6½	*9*	—	7	4½	9½	12½	−1
10	52	11½	9½	3½	4	13	7	*10*	—	6½	4	8½	12½	−2
11	—	13	11	4	5	14	7	*11*	—	7½	4½	9	11	—
12	—	12	10	3	5	13	6	*12*	—	7	5½	10½	13	−½
13	—	11	9	2	5	12	5	*13*	61	6½	5½	10	11	+1
14	—	11	9	2	5	11	4	*14*	—	8	4½	10½	14	−1½
15	51	11½	9½	1½	6	14	6	*15*	—	8	5½	11½	14	−½
16	—	11½	9½	2	5½	11½	4	*16*	—	7	4½	9½	13	−1½
17	57	10½	8½	1½	5	11	4	*17*	—	7½	4½	10	13½	−1½
18	—	11	9	2	5	12½	5½	*18*	55	7	3½	8½	14	−3½
19	—	13	11	4	5	12	5	*19*	—	6½	5½	10	12	—
20	62	12	10	2	6	14½	6½	*20*	59	7	4	9	15	−4
21	—	14	12	5	5	13	6	*21*	—	7	5½	10½	14	−1½
22	—	11½	9½	3	4½	11½	5	*22*	—	7	5	10	14	−2
23	58	11½	9½	3½	4	13	7	*23*	—	7½	5½	11	13	—
24	—	12	10	3½	5½	13	5½	*24*	—	7	4½	9½	13½	−2
25	—	10½	8½	1½	5	13	6	*25*	—	7½	6	11½	13	+½
Valeurs extrêmes		10½–14	8½–12	1½–4½	4–6	9½–14½	3½–7	Valeurs extrêmes		5½–8	3½–6½	8½–12	11–15	−4 à +1

TABLE XVIII.

Pulmonaires récoltées à Messein. (*Année* 1903.)

Les pieds récoltés étaient situés à 3 mètres au moins les uns des autres. Valeurs en millimètres.

Brévistylées								Brévistémonées						
Nos. des plantes	Nos. des dessins schématiques	Hauteur de l'étamine	Distance du l'anthère à la base du calice	Distance de haut du stigmate a la base de l'anthère	Longueur du style et du stigmate réunis	Hauteur totale du calice	Distance du stigmate au bord du calice	Nos. des plantes	Nos. des dessins schématiques	Hauteur de l'étamine	Distance du haut du stigmate à la partie supérieure de l'anthère	Longueur du style et du stigmate	Hauteur totale du calice	Distance du stigmate au bord du calice
1	—	11½	9½	2½	5	11½	4½	*1*	—	7	6	11	13½	−½
2	—	13	11	4	5	13	6	*2*	—	6½	4	8½	10½	—
3	42	13½	11½	5	4½	12	6	*3*	—	6½	6	10½	12½	—
4	—	12	10	2½	5½	12½	5	*4*	—	7	5	10	10	+2
5	—	12	10	3½	4½	12½	6	*5*	—	7	4	9	11	—
6	—	12½	10½	3½	5	12	5	*6*	—	6½	4½	9	10½	+½
7	—	12	10	3	5	13½	6½	*7*	45	7	5	10	8	+2
8	—	11	9	2	5	11	4	*8*	—	7	4	9	11½	−½
9	—	11½	9½	3	4½	10½	4	*9*	—	7	4	9	13	−2
10	—	12	10	3½	4½	11½	5	*10*	—	7	5½	10½	11½	+1
11	—	12	10	2½	5½	13½	6	*11*	—	7½	6	11½	13	+½
12	—	12	10	4	4	10	4	*12*	40	6	6	10	11	+1
13	36–48	11	9	3	4	10	4	*13*	—	6	6	10	13	−1
14	—	12	10	2½	5½	11	3½	*14*	—	7	3½	8½	11½	−1
15	—	11	9	2½	4½	10	3½	*15*	—	7	4½	9½	10½	+1
16	—	12	10	3	5	14	7	*16*	—	6½	5½	10	10	+2
17	—	11½	9½	2½	5	12½	5½	*17*	—	7	5½	10½	12	+½
18	—	13	11	4	5	12	5	*18*	—	6½	5½	9	14½	−3½
19	—	12½	10½	3½	5	15	8	*19*	—	7	4½	9½	11	+½
20	41	11	9	½	6½	12½	4	*20*	33	8	5½	11½	14	−½
21	—	12½	10½	2½	6	13½	5½	*21*	—	6	5½	9½	11½	—
22	—	13	11	4½	4½	13½	7	*22*	—	6½	5½	9	12½	−1½
23	—	13½	11½	4½	5	11½	4½	*23*	—	7	4½	9½	14	−2½
24	—	13	11	4	5	13	6	*24*	—	7	4	9	9	+2
25	—	11½	9½	3	4½	11	4½	*25*	—	7	5	10	11½	+½
26	—	12	10	3½	4½	10½	4	*26*	—	7½	4½	9	11½	−½
27	—	11	9	2½	4½	12½	6	*27*	—	7½	4½	10	14½	−2½
28	—	13	11	3½	5½	10½	3	*28*	—	7	3½	8½	10½	—
29	46	13	11	3½	5½	15	7½	*29*	—	7	5	10	15	−3
30	—	13	11	4½	4½	14	7½	*30*	—	6½	4½	9	11	—
31	—	12½	10½	3½	5	13	6	*31*	—	7	5	10	12	—
32	—	11½	9½	1	6½	11	2½	*32*	43	7½	6	11½	16½	−3
33	—	12	10	3	5	13	6	*33*	—	7	4	9	10½	+½
34	—	12½	10½	3½	5	13½	6½	*34*	34–39	7	3	8	12	−2
35	—	10	8	1	5	12½	5½	*35*	—	7	4½	9½	9½	+2
36	—	14	12	5	5	14½	7½	*36*	—	7	5	10	11½	+½
37	—	10½	8½	2½	4	11	5	*37*	—	7	6	11	11½	+1½
Valeurs extrêmes		10–14	8–12	½–5	4–6½	10–15	2½–8	Valeurs extrêmes		6–8	3–6	8–11½	8–16½	−3½ à +2

H. TABLEAUX DES FRÉQUENCES RELATIVES DES DIVERSES LONGUEURS ÉTUDIÉES.

TABLE XIX.

Hauteur totale du calice. Figs. 49 à 52.

Nombre de plantes présentant les diverses hauteurs.

Hauteurs en millimètres	Laxou			Malzéville		Maxéville		Messein			
	Brévistylées	Brévistémonées		Brévistylées	Brévistémonées	Brévistylées	Brévistémonées	Brévistylées		Brévistémonées	
	Sur 25	Sur 25†	Sur 31	Sur 25	Sur 25	Sur 25	Sur 25	Sur 25‡	Sur 37	Sur 25‡	Sur 37
7½	—	—	—	—	—	—	—	—	—	—	—
8	—	—	—	1	—	—	—	—	—	1	1
8½	—	—	—	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	1	1
9½	—	—	—	—	—	1	—	—	—	—	1
10	—	—	—	1	—	—	—	3	3	2	2
10½	—	1	1	—	2	—	—	1	3	3	5
11	—	—	—	3	—	2	4	3	5	3	4
11½	1	—	—	4	2	3	1	3	3	5	8*
12	3	1	1	4	7*	4	4	3	3	1	3
12½	1	1	1	4	3	3	2	4	6*	2	2
13	6*	6	6	5*	4	9*	4	2	4	3	3
13½	1	4	7	1	1	—	2	4	4	1	1
14	3	5	5	1	4	2	7*	1	2	2	2
14½	2	5	8*	—	2	1	—	—	1	1	2
15	4	1	1	1	—	—	1	1	2	—	1
15½	1	—	—	—	—	—	—	—	—	—	—
16	2	—	—	—	—	—	—	—	—	—	—
16½	1	—	—	—	—	—	—	—	—	—	1
17	—	1	1	—	—	—	—	—	—	—	—
17½	—	—	—	—	—	—	—	—	—	—	—
Type le plus fréquent	13 mm.	14½ mm.		13 mm.	12 mm.	13 mm.	14 mm.	12½ mm.		11½ mm.	
Type moyen (pour la station)	13¾ millimètres			12½ millimètres		13½ millimètres		12 millimètres			

† En ne tenant pas compte des six premières plantes de la série de 31 plantes brévistémonées (Laxou).

‡ En prenant seulement les 25 premières plantes de la série de 37 plantes de Messein.

* Astérisques, indiquant le plus fort chiffre de chaque colonne.

TABLE XIX *bis.*

Hauteur de l'étamine. Figs. 37 à 40.

Distance du haut de l'anthère au bas du calice.

Hauteurs en millimètres		Nombre de plantes présentant les diverses hauteurs					
		Laxou		Malzéville	Maxéville	Messein	
Brévistémonées	*5*	—	—	—	—	—	—
	5½	—	—	—	1	—	—
	6	2	2	3	1	3	3
	6½	6	6	7	4	6	7
	7	8*	10*	6	12*	14	22*
	7½	6	9	7	5	1	4
	8	3	4	2	2	1	1
	8½	—	—	—	—	—	—
	Totaux	25	31	25	25	25	37
Brévistylées	*9½*	—	—	—	—	—	—
	10	—	—	—	—	—	1
	10½	4	—	—	3	—	1
	11	7	—	2	5	4	5
	11½	7*	—	5	7*	4	5
	12	4	—	9*	5	8	10*
	12½	1	—	3	2	3	5
	13	1	—	6	2	4	7
	13½	—	—	—	—	2	2
	14	1	—	—	1	—	1
	14½	—	—	—	—	—	—
	15	—	—	—	—	—	—
	Totaux	25	—	25	25	25	37

TABLE XX.

Hauteur du style et du stigmate au-dessus de l'ovaire. Figs. 41—44.

Longueurs en millimètres du style et du stigmate réunis		Nombre de plantes présentant les diverses tailles					
		Laxou		Malzéville	Maxéville	Messein	
		Sur 25	Sur 31	Sur 25	Sur 25	Sur 25	Sur 37
	3½	—	—	—	—	—	—
Brévistylées	*4*	8*	—	3	4	2	3
	4½	7	—	10*	3	7	10
	5	7	—	8	12*	11*	16*
	5½	1	—	1	4	3	5
	6	2	—	3	2	1	1
	6½	—	—	—	—	2	2
	7	—	—	—	—	—	—
Brévistémonées	*7½*	1	2	1	—	—	—
	8	4	5	4	—	—	1
	8½	5	8	1	6*	2	3
	9	9*	9*	2	3	7*	10
	9½	4	5	5	5	4	5
	10	1	1	7*	4	6	10*
	10½	1	1	1	3	3	3
	11	—	—	4	1	1	2
	11½	—	—	—	2	2	3
	12	—	—	—	1	—	—
	12½	—	—	—	—	—	—

		Laxou	Malzéville	Maxéville	Messein	
Type le plus fréquent (moyenne de fréquence)	Brévistylées	4	4½	5	5	
	Brévistémonées	9	10	8½	10	
		13	14½	13½	15	Moyennes
Moyenne théorique calculée		4·64	4·74	4·94	5·2 4·95	(4·83)
„ „		8·86 8·77	9·52	9·72	9·74 9·70	(9·42)

TABLE XXI.

Distance du stigmate au bord du calice. Figs. 45 à 48.

Distance en millimètres du stigmate au bord du calice		Laxou			Malzéville		Maxéville		Messein			
		Brévistylées	Brévistémonées		Brévistylées	Brévistémonées	Brévistylées	Brévistémonées	Brévistylées		Brévistémonées	
		Sur 25	Sur 25	Sur 31	Sur 25	Sur 25	Sur 25	Sur 25	Sur 25	Sur 37	Sur 25	Sur 37
Styles exsertes de	+ *2½*	—	—	—	—	—	—	—	—	—	—	—
	+ *2*	—	—	—	—	—	—	—	—	—	4	5
	+ *1½*	—	—	—	—	—	—	—	—	—	—	1
	+ *1*	—	—	—	—	—	—	1	—	—	3	3
	+ *½*	—	—	—	—	2	—	3	—	—	5	7*
	0	—	—	—	—	5*	—	4	—	—	4	7
Styles inclus de	− *½*	—	—	—	—	4	—	3	—	—	3	4
	− *1*	—	2	2	—	2	—	2	—	—	2	2
	− *1½*	—	2	2	1	4	—	7*	—	—	1	1
	− *2*	—	6	6	—	5*	—	3	—	—	1	2
	− *2½*	—	3	3	—	1	—	—	—	1	1	2
	− *3*	—	4	7*	—	2	—	—	—	1	—	2
	− *3½*	—	4	5	1	—	1	2	2	2	1	1
	− *4*	—	—	1	3	—	3	1	5	6	—	—
	− *4½*	—	3	3	2	—	1	—	3	3	—	—
	− *5*	1	—	1	5	—	5	—	4	5	—	—
	− *5½*	2	—	—	3	—	3	—	2	3	—	—
	− *6*	2	1	1	6*	—	6*	—	5	8*	—	—
	− *6½*	4	—	—	1	—	3	—	1	2	—	—
	− *7*	5*	—	—	2	—	3	—	2	2	—	—
	− *7½*	3	—	—	—	—	—	—	—	3	—	—
	− *8*	2	—	—	—	—	—	—	1	1	—	—
	− *8½*	3	—	—	—	—	—	—	—	—	—	—
	− *9*	2	—	—	1	—	—	—	—	—	—	—
	− *9½*	1	—	—	—	—	—	—	—	—	—	—
	− *10*	—	—	—	—	—	—	—	—	—	—	—

TABLE XXII.

Distance du stigmate à l'anthère. Figs. 57 à 60.

	Distances en millimètres	Nombre de plantes presentant les diverses distances						Pour 100 25 plantes de chaq. station
		Laxou		Malzéville	Maxéville	Messein		
Brévistylées	0	—		—	—	—	—	—
	½	—		—	—	1	1	1
	1	—		—	—	—	2	—
	1½	2		—	3	—	—	5
	2	3		4	6*	1	1	14
	2½	7*		1	4	2	9*	19
	3	6		7	4	5	6	22
	3½	5		6*	4	4	9*	19
	4	1		4	2	4	4	11
	4½	—		2	1	2	3	5
	5	1		1	1	1	2	4
	5½	—		—	—	—	—	—
		25		25	25	25 ‡	37	100
Brévistémonées	1	—	—	—	—	—	—	—
	1½	—	1	—	—	—	—	—
	2	2	2	—	—	—	—	2
	2½	0	1	—	—	—	—	—
	3	3	5	1	—	1	1	5
	3½	7	8*	5	4	1	2	17
	4	6	6	4	2	5	6	17
	4½	4	5	6*	7*	3	8*	20
	5	2	2	3	4	3	6	12
	5½	—	—	2	6	7	7	15
	6	1	1	2	1	5	7	3
	6½	—	—	—	1	—	—	1
	7	—	—	1	—	—	—	1
	7½	—	—	—	—	—	—	—
		25 †	31	25	25	25 ‡	37	100

† En ne tenant pas compte des 6 premières plantes de la série des 31 plantes brévistémonées de Laxou.

‡ En ne tenant compte que des 25 premières plantes de la série de 37 plantes de Messein.

I. VARIABILITÉ COMPARATIVE DANS LES QUATRE STATIONS.

TABLE XXIII A.

Variabilité comparée de 25 échantillons observés dans quatre stations différentes.

(Ce tableau, qui donne seulement l'étendue empirique de la variation, a surtout pour but de montrer les dimensions habituelles des plantes des stations considérées, en vue de les comparer aux dimensions des plantes d'autres stations de l'espèce.)

Caractères étudiés	Stations	Variabilité de l'espèce, écart observé	Variabilité des deux types brévistylé et brévistémoné		Distance des sommets de plus grande fréquence. Différence entre les deux types de grande fréquence	Valeur minimum du type		Valeur moyenne de grande fréquence		Valeur maximum du type	
						Brévistylé	Brévistémoné	Du type brévistylé	Du type brévistémoné	Brévistylé	Brévistémoné
Hauteur totale du calice	Laxou	7½	6	7½	1½	11	10	13	14½	17	17½
	Malzéville	8	8	5	1	7½	10	13	12	15½	15
	Maxéville	6½	6	5	1	9	10½	13	14	15	15½
	Messein	9½	6	9½	1	9½	7½	12½	11½	15½	17
Hauteur totale des étamines	Laxou	9	4½	3	4	10	5½	11	7	14½	8½
	Malzéville	8	3	3½	5	10½	5½	12	7	13½	9
	Maxéville	9½	4½	3½	4½	10	5	11½	7	14½	8½
	Messein	8½	3½	3	5	10½	5½	12	7	14	8½
Hauteur totale du style et du stigmate	Laxou	7½	3	4	5	3½	7	4	9	6½	10½
	Malzéville	8	3	4½	5½	3½	7	4½	10	7	11½
	Maxéville	9	3	4½	3½	3½	8	5	8½	6½	12½
	Messein	8½	3½	4	4	3½	8	5	9	7	12
Distance du stigmate au bord du calice	Laxou	9½	5½	6	4	−4½	−1	−7	−3	−10	−6½
	Malzéville	10½	8½	4½	4	−1	+1	−6	−2	− 9½	−3½
	Maxéville	9	4½	6	4½	−3	+1½	−6	−1½	− 7½	−4½
	Messein	11	6½	6½	6	−2	+2½	−6	—	− 8½	−4
Distance du stigmate à l'anthère	Laxou	5½	4½	5½	1	1	1	2½	3½	5½	6½
	Malzéville	6	4	5	1½	1½	2½	3	4½	5½	7½
	Maxéville	6	4	4	2½	1	3	2	4½	5	7
	Messein	6½	5½	4	1½	—	2½	3	4½	5½	6½

TABLE XXIII B.

Comparaison des valeurs obtenues dans quatre stations différentes.

A. Plantes brévistémonées.

Caractère étudié	Laxou			Malzéville			Maxéville			Messein		
	M	σ	$100\frac{\sigma}{M}$	M	σ	$100\frac{\sigma}{M}$	M	σ	$100\frac{\sigma}{M}$	M	σ	$100\frac{\sigma}{M}$
Hauteur totale du calice	13·72	1·076	7·83	12·64	1·100	8·70	12·64	1·156	9·14	11·86	1·729	14·58
Hauteur totale des étamines	7·11	0·549	7·72	6·96	0·582	8·36	7·00	0·548	7·83	6·91	0·833	12·06
Hauteur totale du style	8·77	0·682	7·78	9·52	1·024	10·76	9·72	1·021	10·50	9·70	0·874	9·01
Distance du stigmate au bord du calice	– 2·95	1·152	—	– 1·10	1·029	—	– 1·10	1·288	—	– 0·16	1·489	—
Distance du stigmate à l'anthère ...	3·66	0·936	25·57	4·52	0·932	20·62	4·76	0·626	13·15	4·88	0·817	16·74

B. Plantes brévistylées.

Caractère étudié	Laxou			Malzéville			Maxéville			Messein		
	M	σ	$100\frac{\sigma}{M}$	M	σ	$100\frac{\sigma}{M}$	M	σ	$100\frac{\sigma}{M}$	M	σ	$100\frac{\sigma}{M}$
Hauteur totale du calice	13·86	1·375	9·92	12·10	1·342	11·17	12·44	1·061	8·53	12·27	1·383	11·27
Hauteur totale des étamines	11·48	0·806	7·02	12·12	0·621	5·12	11·68	0·847	7·25	12·09	0·884	7·31
Hauteur totale du style	4·64	0·592	12·76	4·82	0·564	11·70	4·94	0·554	11·22	4·96	0·574	11·57
Distance du stigmate au bord du calice	– 7·22	1·167	16·16	– 5·32	1·392	26·17	– 5·64	0·878	15·57	– 5·32	1·319	24·79
Distance du stigmate à l'anthère ...	2·84	0·771	27·15	3·30	0·800	24·24	2·82	0·942	33·40	3·14	1·011	32·20

TABLE XXIV.

Distance du stigmate au bord du calice.

	Laxou	Malzéville	Maxéville	Messein
Styles inclus	100 par 100	72	69	38
Styles égaux au calice	0	20	15	19
Styles ex.	0	8	16	43

Longueur du style (l) *relativement au calice* (l'). $l' - l = d$.

Sur 100 styles il y a

	Laxou	Malzéville	Maxéville	Messein
$l < d$	92	60	60	55
$l = d$	8	20	20	13
$l > d$	0	20	20	32

Donc, pour les brévistylées comme pour les brévistémonées le style a la plus grande capacité de croissance à Messein par rapport à la capacité de croissance du calice.

L. CARACTÈRES GÉNÉRAUX DES RACES GÉOGRAPHIQUES OBSERVÉES.

Si l'on compare les polygones de fréquence obtenus avec 25 plantes d'une localité (Messein) et ceux qu'on obtient avec 37 plantes du même lieu, on constate que les sommets et les limites latérales de ces polygones correspondent sensiblement aux mêmes points de la ligne des abscisses.

La même conclusion est exacte pour les polygones obtenus à Maxéville avec les récoltes simultanées de 25 plantes et 100 plantes.

Malgré la faiblesse relative du chiffre 25, il n'y a donc pas de causes d'erreurs suffisantes, pour nous interdire de tirer des conclusions relatives aux races géographiques de la Pulmonaire des 4 localités comparées. Ces comparaisons portent sur les points suivants :

1. *Hauteur totale du calice.* 2. *Distance du stigmate au bord du calice.* 3. *Hauteur de l'étamine.* 4. *Distance du stigmate à l'anthère.*

Si on compare soit les chiffres des Tables XXIII A et B soit les graphiques (Figs. 37—48 ; 49—52 ; 57—60) on voit tout de suite qu'il y a des variations assez accusées dans les quatre stations étudiées.

Ce sont les plantes brévistémonées de Messein qui ont montré le calice le plus variable, avec tendance vers les petites tailles : la plus fréquente étant seulement d'une longueur de 11 mill. $\frac{1}{2}$.

Si l'on suppose que la grande capacité de croissance du calice correspond à une vigueur plus grande de la fleur on peut penser que les autres parties de la fleur seront peut-être influencées dans le même sens. D'autre part si la capacité de croissance du calice est faible cela peut provenir d'un arrêt de développement de l'organe. Dans cette hypothèse un organe voisin, le style par exemple, pourrait bénéficier de cet arrêt de développement et exagérer lui-même sa propre capacité de croissance.

Si on consulte la Table (XXIII B) on voit que, parmi les 4 types brévistylés, c'est justement le type brévistylé Laxou qui a le calice du type moyen le plus grand tandis que c'est lui qui a le style du type moyen le plus petit.

De même, parmi les 4 types brévistémonés c'est le type brévistémoné Messein qui a sensiblement le style du type moyen le plus grand et le calice du type moyen le plus petit.

Les chiffres de la Table XXIII B semblent bien démontrer ce fait d'ailleurs visible aussi sur les mensurations individuelles *faites sur des centaines d'échantillons :*

La longueur du calice et la longueur du style sont deux quantités qui varient en sens inverse, aussi bien chez les fleurs brévistylées que chez les plantes brévistémonées, en passant d'une race à une autre.

Il était naturel de penser que cela entraîne cette autre conclusion :

Les types de styles les plus inclus appartiennent aux fleurs ayant les plus grands calices, et inversement les types de styles les plus exsertes appartiennent aux fleurs ayant les plus petits calices.

Il en est ainsi dans beaucoup de cas, et la comparaison des types moyens est démonstrative à cet égard :

Distance du stigmate au bord du calice.

Localités	Pour le type de grande fréquence de chaque station			Pour le type moyen		
	Brévistylées	Brévistémonées	Différence entre les deux types	Brévistylées	Brévistémonées	Différence
Laxou ...	−7 mill.	−3 mill.	4	−7·22	−2·95	4·27
Maxéville	−6 ,,	−1½ ,,	4½	−5·64	−1·10	4·54
Malzéville	−6 ,,	−2 ou 0	4 ou 6	−5·32	−1·10	4·20
Messein...	−6 ,,	+½ ou 0	6½	−5·32	−0·16	5·16

Il y a évidemment, à Laxou, tendance à la production d'une race à grand calice, à style court et très inclus dans le calice ; tandis qu'à Messein on voit qu'il y a une tendance très accentuée à la production d'une race à calice court et à style long exserte. Voyez Table XIV.

Ceci d'ailleurs est contrôlé aussi par les mensurations individuelles. Nous avons noté, en effet, que chez certaines fleurs il y a une sorte de nanisme floral, c'est-à-dire une réduction proportionnelle des diverses parties.

On trouve donc ici une démonstration que le type géographique en formation est au moins partiellement fixé.

On trouvera par exemple à Messein des fleurs à styles très exsertes de deux sortes :

1^er^ cas. Celles qui ont un calice plus court que la moyenne du type et qui ont un style plus long que la moyenne du type.

C'est une race en formation, ne tenant peut-être sa particularité que comme variation individuelle.

2^e^ cas. Celles qui ont un calice plus grand et un style plus grand, ou bien encore un calice plus petit et un style plus petit, que la moyenne du type.

Celles-là sont des races fixées, au moins partiellement : elle tiennent la particularité qui les caractérise, d'une influence héréditaire.

Nous pouvons comprendre la formation de ces races en constatant que l'arrêt de développement du calice entraîne le plus grand développement du style ou inversement.

On peut supposer que dans le bouton floral le temps qui sépare le début de la croissance des deux organes est un facteur important qui modifie leur capacité de croissance, et comme conséquence amène la formation de races spéciales.

De même pendant le grand développement de la fleur, au moment de son épanouissement il suffit d'une influence du milieu physique (pluie...température...) pour expliquer la variation des proportions relatives des deux organes ; ceux-ci ne se trouvant pas à la même période de leur évolution.

Types moyens théoriques calculés (*Moyennes arithmétiques*).

Conclusions relatives à la variabilité dans les quatre localités étudiées.

1. Le style a une capacité de croissance moyenne qui est plus forte et va en s'accroissant dans l'ordre suivant : Laxou, Malzéville, Messein, Maxéville.

Soit 100 la capacité de croissance moyenne du style des brévistémonées à Laxou ; elle sera 110·83 à Maxéville, soit 10·8 % en plus.

Soit 100 la capacité de croissance moyenne du style des brévistylées à Laxou ; elle sera 106·46 à Maxéville, soit 6·4 % en plus.

2. Les tailles extrêmes du style qui ont été observées sont plus grandes à Maxéville. Mais il est vrai que le nombre des échantillons observés a été plus grand qu'ailleurs. L'accroissement se fait dans le même ordre : Laxou, Malzéville, Messein, Maxéville, pour les Brévistémonées.

C'est donc à Maxéville qu'on a trouvé le plus grand style et à Laxou qu'on a trouvé le plus petit.

Il en est de même pour les styles; ils correspondent aux plus grandes et aux plus petites étamines.

3. Les tailles moyennes du calice sont au contraire plus grandes à Laxou (13·86 et 13·72).

La variation semble se faire en sens inverse du style.

Soit 100 la capacité de croissance moyenne du calice des brévistémonées à Laxou ; elle sera 90·53 à Maxéville, soit 9·5 en moins ; et 86 à Messein, soit 14 °/₀ en moins.

Soit 100 la capacité de croissance moyenne du calice des brévistylées à Laxou ; elle sera 89·86 à Maxéville, soit 10·2 °/₀ en moins ; et 88·72 à Messein, soit 11·3 °/₀ en moins.

4. Le type moyen du calice est remarquablement fixé dans chaque station pour les deux types brévistylés et brévistémonés.

	Types moyens (calice)		Types moyens (style)	
	Brévistémonées	Brévistylées	Brévistémonées	Brévistylées
Laxou	13·72 mm.	13·86 mm.	8·77 mm.	4·64 mm.
Malzéville	12·64 „	12·10 „	9·52 „	4·82 „
Messein	11·86 „	12·27 „	9·70 „	4·96 „
Maxéville	12·64 „	12·44 „	9·72 „	4·94 „

La différence relativement plus accusée entre les deux chiffres 11·86 et 12·27 de Messein provient de ce fait que à Messein le calice des échantillons du type des brévistémonées a été trouvé très variable dans les échantillons observés (8 à 16 mill.) tandis que le type des brévistylées est plus concentré autour du type moyen (10 à 15).

C'est bien là ce qui explique la faiblesse du chiffre 11·8. Le chiffre 12·28 est tout-à-fait normal.

5. Le pistil a ordinairement une longueur un peu moindre que l'étamine du type inverse, surtout en ce qui concerne les pistils des fleurs brévistémonées :

	Types moyens théoriques (Valeurs en millimètres)				Différences entre le pistil et les étamines des types inverses	
	Brévistémonées		Brévistylées			
	Pistil	Étamines	Pistil	Étamines	Étamines et pistils de grande taille	Étamines et pistils de petite taille
Laxou	10·77	7·11	6·64	11·48	0·71, soit 6 °/₀	0·47, soit 6·6 °/₀
Malzéville	11·52	6·96	6·82	12·12	0·60 „ 4·9 °/₀	0·14 „ 1·9 °/₀
Messein	11·70	6·91	6·96	12·09	0·39 „ 3·2 °/₀	0·05 „ 0·7 °/₀
Maxéville	11·72	7	6·94	11·68	0·04 „ 0·3 °/₀	0·06 „ 0·8 °/₀
Moyennes	11·43	6·99	6·82	11·84		

Dans les échantillons qui ont été passés en revue, et mesurés avec attention, le pistil d'une fleur brévistylée et l'étamine d'une fleur brévistémonée d'une même station sont ordinairement, assez rigoureusement, d'une même taille moyenne. Le pistil d'une fleur brévistémonée et l'étamine d'une fleur brévistylée d'une même station sont, seulement approximativement, de même taille moyenne, l'étamine étant ordinairement un peu plus grande, au maximum de $\frac{1}{10}$.

6. La distance du stigmate à l'anthère est très différente chez les brévistémonées et chez les brévistylées. Elle est plus faible de $\frac{1}{3}$ environ chez les brévistylées. C'est, comme on le voit pour *P. officinalis* une conclusion semblable à celle qui a été obtenue par Darwin avec 10 échantillons de *P. angustifolia*:

	Brévistémonées	Brévistylées	Différence des deux types	Moyennes des 2 types
Laxou ...	3·66 mm.	2·84 mm.	0·82, soit 28 °/o	3·25
Malzéville ...	4·52 „	3·30 „	1·20 „ 35 °/o	3·91
Messein ...	4·88 „	3·14 „	1·74 „ 47 °/o	4·01
Maxéville ...	4·76 „	2·82 „	1·94 „ 68 °/o	3·79
Chiffre moyen	4·45 „	3·02 „	1·42, soit 47 °/o	3·73

Si on représente par 100 la distance moyenne du stigmate à l'anthère chez les fleurs brévistylées, la distance est de 147 chez les brévistémonées, soit une différence de 47 p. 100.

D'autre part cette différence est plus faible chez les deux types de la station de Laxou. Elle est plus forte chez les types de Messein et Malzéville, et atteint 68 °/o à Maxéville.

Si on représente par 100 le chiffre de la moyenne des 2 types: 3·73, les valeurs correspondants des différentes stations sont:

Laxou	87·1
Malzéville	105
Messein	107·5
Maxéville	101·6.

Les stations de Messein et Laxou diffèrent donc de près de 20 p. 100, soit $\frac{1}{5}$.

Variabilité et fixité de l'hétérostylie de la Pulmonaire.

Si l'on veut apprécier la *variabilité et la fixité relatives de l'espèce,* dans les quatre stations, il y a lieu de ne pas s'en tenir à la comparaison des types de grande fréquence fournis par les graphiques. Il faut calculer le type moyen théorique, qui est obtenu en faisant la moyenne arithmétique des diverses longueurs observées.

Après avoir vu défiler des tailles extrêmes différentes, et de fréquence respective assez variable, on est surpris de constater, pour l'étamine et pour le pistil, le peu de différence présentée par les moyennes théoriques calculées, dont les chiffres figurent à la page 446.

	Hauteur de l'étamine au-dessus de la base du calice		Hauteur du pistil au-dessus de la base du calice	
	Brévistylées	**Brévistémonées**	**Brévistylées**	**Brévistémonées**
Écart des extrêmes	5·6 °/₀	3 °/₀	8 °/₀	7 °/₀
Amplitude des variations extrêmes observées par rapport au chiffre de la moyenne générale	3 à 4 °/₀	2 °/₀	3 à 4 °/₀	4—5 °/₀

Il ressort de ces chiffres

(1) Que l'amplitude ordinaire de la variation est relativement faible.

(2) Que l'étamine est moins variable de longueur que le style.

(3) Que les fleurs brévistémonées semblent un peu moins variables que les fleurs brévistylées.

La première conclusion explique pourquoi l'hétérostylie peut se maintenir malgré la multiplicité des tailles observées, et malgré le fait de l'existence de petites races géographiques très localisées. On peut supposer que si l'hétérostylie a été perdue par certaines espèces de pulmonaires c'est que, à un moment donné l'amplitude de la variation moyenne théorique a été très supérieure à 10 °/₀ et n'est pas rentrée ensuite dans les limites de ce chiffre.

Darwin avait émis l'hypothèse que certaines Pulmonaires présentaient peut être une hétérostylie mal fixée. Ce cas particulier explique en outre que *l'évolution graduelle vers un type non hétérostylé semble ne pas exister à Nancy.* Pour que l'hétérostylie disparaisse chez un type hétérostylé habituellement, il ne suffit pas qu'une cause brusque affole le type, et le rende très variable, il faut que le type moyen lui-même soit très modifié.

Si l'on étudie la variation de l'hétérostylie de la Pulmonaire on voit que la variabilité spécifique doit s'accuser par la variation de la position de l'axe de plus grande fréquence qui peut être repoussée à droite ou à gauche.

Il faut constater que la conclusion finale n'est pas celle que pourrait laisser entrevoir les mesures biométriques prises isolément sur quelques échantillons seulement :

L'hétérostylie de Pulmonaria off. semble très peu variable en tant que caractère fondamental de l'espèce. Elle se manifeste avec des modalités très variées, mais elle est bien fixée, au moins dans les localités observées.

La variation la plus importante observée dans les diverses stations consiste dans les différences relatives de développement du calice et du style : *Il y a en* *certains points de la station de Messein une race de Pulmonaire officinale à style très exserte par rapport au calice* et, au contraire, *la station de Laxou offre une race à style très inclus.*

On peut dire de même que certaines races tendent à présenter chez les deux types de fleurs *une distance très variable du stigmate à l'anthère.* Cette distance étant beaucoup plus grande chez les fleurs dolichostylées.

CONCLUSIONS GÉNÉRALES.

1. Quelles que soient les variations individuelles de la taille de *Pulmonaria officinalis,* les types morphologiques et les dimensions des organes floraux ne sont pas modifiés par les variations de la taille des tiges. Table IV, page 411, et Table VI, page 413.

La distance du stigmate à l'anthère, signalée par Darwin comme variable chez *Pulmonaria angustifolia,* est aussi très variable chez *P. officinalis*; mais cette variation ne dépend pas de la taille des plantes. Fig. 3, page 415.

D'une façon générale, chez les petites plantes les dimensions des organes floraux subissent des variations un peu plus grandes que chez les grandes plantes. Chez celles-ci le type est plus concentré autour des dimensions moyennes et fréquentes.

2. Les grandes tiges présentent un plus grand nombre de fleurs : soit, en moyenne, 1560 fleurs pour 100 grandes plantes, contre 1360 fleurs pour 100 petites plantes. Le nombre moyen des fleurs par individu n'est pas très différent pour les plantes brachystylées, et les plantes dolichostylées : on trouve quelquefois, chez les premières, un nombre un peu plus grand de fleurs (Fig. 5, page 423), mais Hildebrand a généralisé à tort qu'il en était toujours ainsi. Il y a des localités où le nombre moyen de fleurs est tout à fait le même pour les plantes brachystylées ou brévistylées et pour les plantes brévistémonées ou dolichostylées. Fig. 7 et Fig. 10, page 454.

La floraison plus ou moins abondante ne semble donc pas en rapport avec l'hétérostylie.

3. Si on explore une surface de 1 ou 2 hectares des bois des environs de Nancy, en prenant toutes les Pulmonaires rencontrées, les plantes brévistylées paraissent plus nombreuses, d'environ $\frac{1}{10}$ à $\frac{1}{9}$, que les plantes dolichostylées ou brévistémonées. Mais ce calcul présente une certaine incertitude ; le résultat obtenu dépend peut-être de l'étendue prise comme unité de surface, ou même de la dernière période du rythme météorologique. On peut admettre, en effet, que les deux types ne sont pas tout à fait dans les mêmes conditions, pour résister, par exemple, à des pluies qui peuvent à un moment donné, produire sur les deux types une coulure inégalement défavorable.

4. Les Tables X et XI (pp. 420, 421) montrent très nettement la comparaison des dimensions des fleurs brévistylées et des fleurs brévistémonées. Les différences

sont peu nombreuses. Les deux types oscillent autour des mêmes dimensions moyennes, et les chiffres extrêmes observés dans une centaine d'échantillons sont assez peu différents. Il y a pourtant une particularité très intéressante à noter, c'est l'inégalité de la distance entre le stigmate et l'anthère. Elle est chez les brévistylées plus faible d'au moins $\frac{1}{3}$ de ce qu'elle est chez les brévistémonées. Dans certaines stations ces deux distances sont entre elles comme 100 est à 172. Pour la moyenne des chiffres de quatre stations des environs de Nancy, on trouve, pour les brévistylées une valeur moyenne de 3·02 mm. et pour les brévistémonées 4·45 mm., soit, par rapport au chiffre le plus faible des deux, 47 p. 100 en plus (voir page 447. Figs. 14, 55, 57 à 60).

Il est curieux de constater l'absolue fixité de l'hétérostylie avec un caractère aussi variable que celui que nous venons d'examiner: le libre croisement maintient la constance des dimensions moyennes du style et de l'étamine, sans réaliser la constance de la différence des longueurs de ces organes dans chaque fleur (voir page 446 et les graphiques, Figs. 57—60, 37—40, 41—44).

5. L'influence du climat de l'année ne semble pas modifier la capacité de croissance moyenne, et les capacités de croissance extrêmes des diverses parties de la fleur hétérostylée. Tables XIV *a* et XIV *b*, pp. 424—29, et Figs. 61—63, 53—56.

6. Si on compare des Pulmonaires de quatre stations différentes (Laxou, Malzéville, Maxéville, Messein) on voit qu'il y a des différences assez accusées. Fig. 6, Tables XXIII A et B, pages 441—2.

La longueur du calice et la longueur du style sont deux quantités qui varient en sens inverse aussi bien chez les plantes brévistylées que chez les plantes brévistémonées.

Certaines stations, comme Messein par exemple, peuvent posséder des races de Pulmonaires à styles exsertes du calice, tandis que d'autres (Laxou) donnent des fleurs à styles profondément inclus dans le calice. Il est à remarquer d'ailleurs que les fleurs brévistylées de Messein présentent aussi des étamines moins incluses que celles de Laxou (voir page 451 les dessins des types moyens théoriques, et les types extrêmes de ces deux localités).

La distance du stigmate à l'anthère n'est pas la même dans les diverses stations: pour les brévistémonées elle varie de 3·66 mm. à 4·80 mm.; pour les brévistylées elle varie de 2·74 à 3·34. Cela représente une différence qui, par rapport au chiffre le plus faible, peut atteindre 31 °/₀ pour les premières, et 21 °/₀ pour les secondes, page 447.

Ainsi nous pouvons conclure que dans chaque station il est possible de trouver des sortes de races géographiques locales orientées vers une modification spéciale des proportions des divers organes.

Pour ce qui est du phénomène de l'hétérostylie il constitue, chez *Pulmonaria officinalis*, un caractère specifique très peu variable.

Cette hétérostylie est plus ou moins accusée chez les divers individus, et nous avons même trouvé une plante où la distance du stigmate à l'anthère était presque

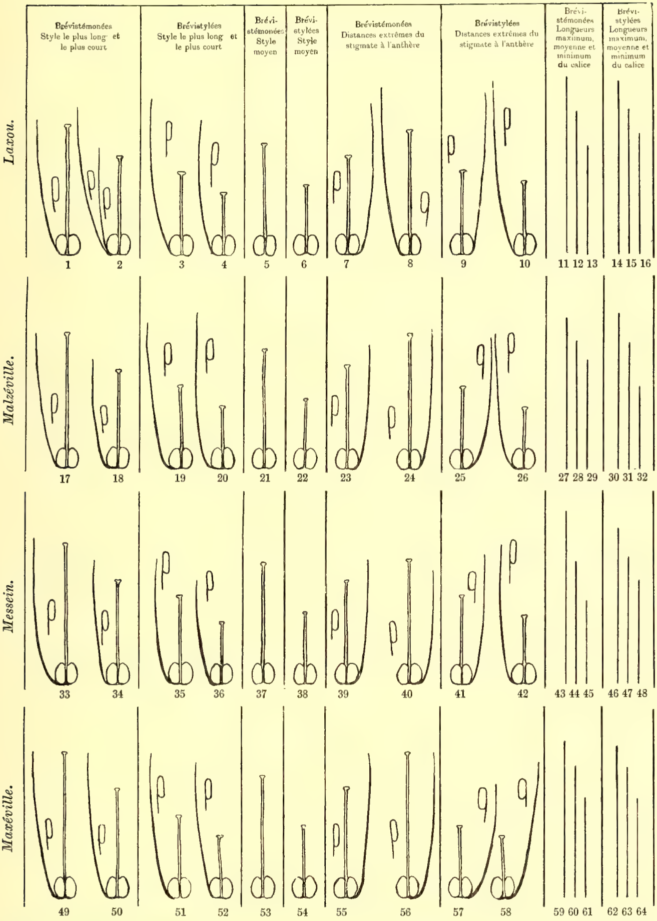
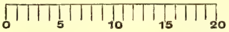

Brévistémonées Style le plus long et le plus court
Bréviatylées Style le plus long et le plus court
Brévi-stémonées Style moyen
Brévi-stylées Style moyen
Brévistémonées Distances extrêmes du stigmate à l'anthère
Brévistylées Distances extrêmes du stigmate à l'anthère
Brévi-stémonées Longueurs maximum, moyenne et minimum du calice
Brévi-stylées Longueurs maximum, moyenne et minimum du calice
Laxou.
Malzéville.
Messein.
Maxéville.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64

FIG. 6. Schémas représentant les types extrêmes ou caractéristiques de Pulmonaires pour les quatre stations étudiées. (Voyez Tables XV, XVI, XVII, XVIII, pp. 432—435.)



Millimètres

nulle*. Mais, malgré les types de fleurs si différents, les types moyens calculés sont d'une remarquable fixité pour les races des quatre localités étudiées (voir page 446). Et pourtant la loi de fréquence est légèrement modifiée dans beaucoup de cas (voir les graphiques, 37—52 et 57—60, pages 457—8).

7. L'ensemble du travail donne des renseignements sur la nature des courbes relatives à la variation de longueur des organes des deux types d'une fleur hétérostylée. Les graphiques 53 à 56, établis avec des chiffres suffisamment nombreux, et comparés aux autres graphiques du mémoire, permettent de schématiser les résultats en donnant les courbes qui synthètisent les nombreuses mensurations biométriques de ce travail.

a. En ce qui concerne *les longueurs du style et de l'étamine* des deux types de fleurs, les courbes de fréquence de ces longueurs sont des courbes hyperbinomiales. Une certaine asymétrie pourtant se manifeste sur les courbes du style dont l'axe tend à être rejeté vers la gauche. Fig. 53.

Les sommets de grande fréquence sont plus surélevés pour les styles des fleurs brévistylées que pour les autres, Fig. 53; c'est l'inverse pour les sommets de fréquence des étamines. Figs. 39 et 43, 38 et 42.

Sur 1000 échantillons de plantes brévistémonées il y en a environ 450 présentant des étamines moyennes, et 275 présentant des styles moyens.

Sur 1000 échantillons de plantes brévistylées on trouve environ 325 plantes à étamines moyennes, et 400 plantes à styles moyens.

Si on ajoute deux millimètres pour la hauteur de l'ovaire, aux longueurs les plus fréquentes des *styles*, on obtient la hauteur des *pistils* les plus fréquents des deux types (7 et $11\frac{3}{4}$ mm.). Les hauteurs des étamines des types inverses sont justement aussi 7 et $11\frac{3}{4}$ pour les types les plus fréquents.

Le "type théorique," des Pulmonaires de Maxéville, vérifie exactement cette relation. Les types des autres stations peuvent s'en écarter seulement au maximum de 6 °/₀ (Laxou), (voir page 446), et c'est généralement l'étamine qui est un peu plus grande que le style de la fleur inverse. Cette fixité assez remarquable du type moyen théorique de l'étamine et du pistil s'oppose à la variabilité si considérable, signalée précédemment, pour les valeurs moyennes théoriques de la distance du stigmate à l'anthère.

On voit, par les graphiques, que la longueur du pistil comme la longueur de l'étamine peuvent varier de 5 à 15 millimètres. Voyez aussi Tables XXIII A et B, pages 441—2.

L'étamine longue et le style long ont plus de possibilité de variation (9 à 15 et 7 à 14) que l'étamine courte et le style court (5 à 9 et 4 à 8).

---

* Le présent travail n'en démontre pas moins qu'il n'existe pas à Nancy de "type général" de Pulmonaire ayant le style et les étamines de même taille. Plusieurs auteurs français admettent l'existence de ce troisième type général. Il est possible que quelques types extrêmes, analogues à celui qui est mentionné ici, aient éte observées. Mais existe-t-il une localité où ce type est fixé?

b. La distance du stigmate à l'anthère est différente dans les deux types brachystylés et dolichostylés, et plus grande dans ce dernier, Fig. 55. Les deux courbes de fréquence sont binomiales, d'égale hauteur; la distance de leurs axes de fréquence est de 0·8 à 2 millimètres, soit de 25 à 70 °/₀ de la valeur totale.

c. La distance du stigmate au calice est représentée par deux courbes binomiales normales, Fig. 56. La courbe des brévistémonées étant plus haute, avec axe de grande fréquence sur –1, c'est-à-dire que le stigmate est inclus dans le calice de 1 millimètre. La courbe des fleurs brévistylées est moins haute et par conséquent plus étalée. Elle indique une très grande variabilité, depuis 0 jusque –12, c'est-à-dire que le stigmate peut affleurer à la pointe des lobes du calice ou rester inclus de 12 millimètres. L'axe de grande fréquence est sur – 6.

d. La hauteur du calice est représentée par une seule courbe pour les deux types de fleurs. L'hétérostylie n'influence donc pas les dimensions de cet organe, d'ailleurs très variable. Fig. 54.

La courbe est probablement binomiale avec une région à droite de l'axe de plus grande fréquence, qui est presque toujours irrégulière et tend à se surélever avec affaissement immédiat.

C'est la seule des courbes qui soit moins précisée et moins certaine. Cette incertitude résulte peut-être de ce fait que tous les lobes du calice ne sont pas toujours égaux, ce qui donne un flottement dans les mensurations. Dans ce cas en effet le chiffre exact à retenir serait la moyenne des 5 chiffres fournis par les 5 lobes. Or ce calcul n'était pas réalisable rapidement et n'a pas été fait. On prenait le chiffre le plus fort. Comme on le voit c'est dans les grandes tailles que survient la perturbation de la courbe. Or nous avons observé que les calices à dents inégales étaient surtout fréquents dans les calices très développés.

L'EXPLICATION DES GRAPHIQUES.

Figs. 7, 12, 13 à 18. Réprésentation graphique des chiffres du Tabl. VIII. Maxéville, 3ᵉ lot, 1903, pp. 417—424; Comparaison des plantes brévistylées —— et des plantes brévistémonées - - - -.

Figs. 8, 9, 9 *bis* (Distance du stigmate au bord du calice), 10, 11. Comparaison graphique entre les plantes de grande taille - - - - et les plantes de petite taille —— récoltées à Maxéville 1902. Toutes les plantes brévistémonées. Voyez Tabl. V, p. 412.

Figs. 19—27. Réprésentation graphique des chiffres des Tabl. IX et XII. Voyez pp. 419, Messein, et 425, Maxéville, 1ᵉʳ lot, 1903.

Figs. 28—36. Réprésentation graphique des chiffres du Tabl. XII. Voyez p. 425. Fig. 31 et Fig. 35, *au lieu de* inclu *lisez* exserte.

Figs. 37—48. Réprésentation graphique de l'influence de la station. Figs. 37—40, Hauteur totale des étamines, p. 437; Figs. 41—44, Longueur du style, p. 438; Figs. 45—48, Distance du stigmate au bord du calice, p. 439; Figs. 46 et 47, *au lieu de* inclus *lisez* exsertes; Figs. 49—52, Hauteur totale du calice, p. 436; Figs. 57—60, Distance du stigmate à l'anthère, p. 440.

Figs. 53—63. Réprésentation graphique de l'influence du climat annuel. Figs. 53—56, Nombres totaux à Maxéville en 1903, p. 425; Figs. 61—63, Nombres totaux à Maxéville en 1902, p. 428.

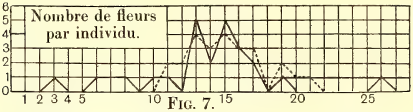
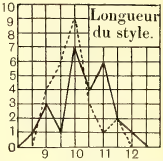


FIG. 7.



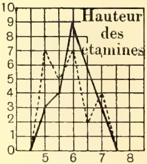
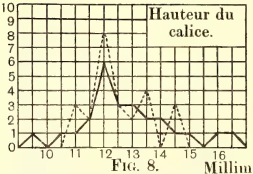


FIG. 10. Millimètres. FIG. 11.



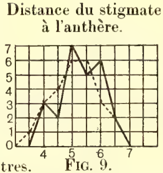
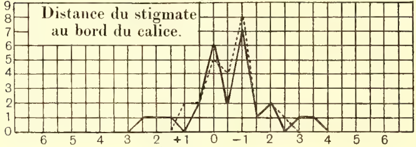
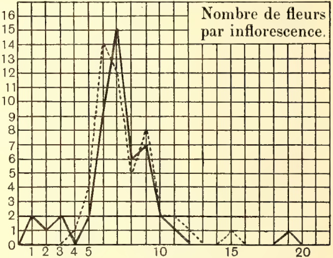


FIG. 8. Millimètres. FIG. 9.

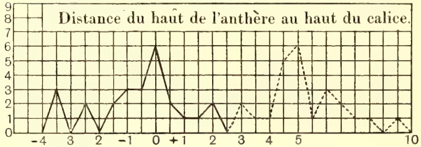


Millimètres.

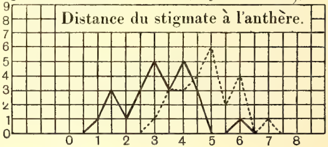


Millimètres. FIG. 12.

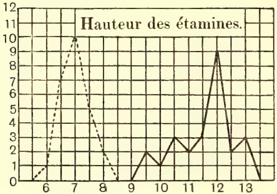
Comparaison graphique entre les plantes de grande taille (- - - - -) et les plantes de petite taille (——) récoltées à Maxéville 1902.—Toutes les plantes brévistémonées (voyez Tabl. V).



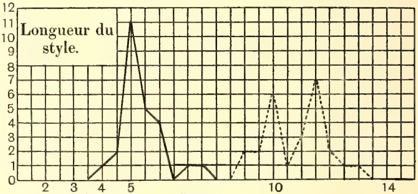
Millimètres. FIG. 13.



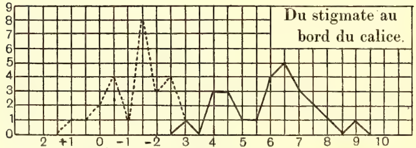
Millimètres. FIG. 14.



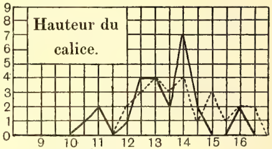
Millimètres. FIG. 15.



Millimètres. FIG. 16.

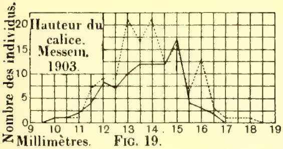


Millimètres. FIG. 17.

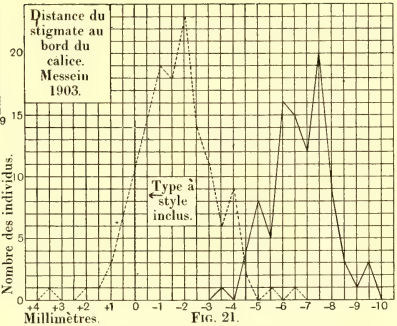


Millimètres. FIG. 18.

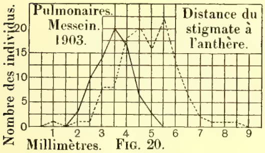
Représentation graphique des chiffres du Tabl. VIII. Plantes brévistylées ——
Plantes brévistémonées - - - - - - Un degré de l'échelle verticale = un individu.



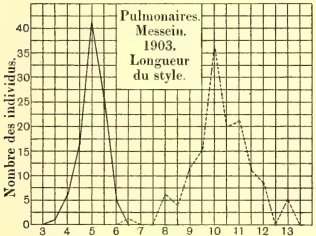
Millimètres. FIG. 19.



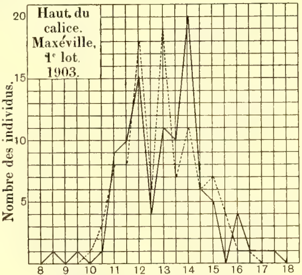
Millimètres. FIG. 21.



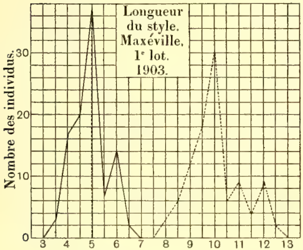
Millimètres. FIG. 20.



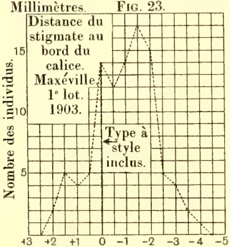
Millimètres. FIG. 22.



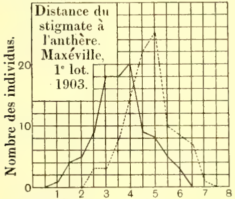
Millimètres. FIG. 23.



Millimètres. FIG. 24.



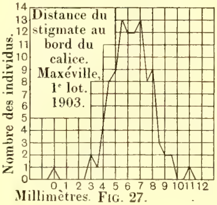
Millimètres. FIG. 26.



Millimètres. FIG. 25

Brévistylées
——
Brévistémonées

Voyez
Tabl. IX et XII.



Millimètres. FIG. 27.

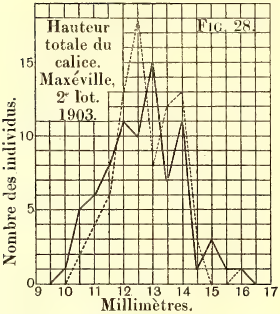


FIG. 28. Hauteur totale du calice. Maxéville, 2e lot. 1903.

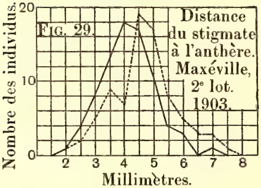


FIG. 29. Distance du stigmate à l'anthère. Maxéville, 2e lot. 1903.

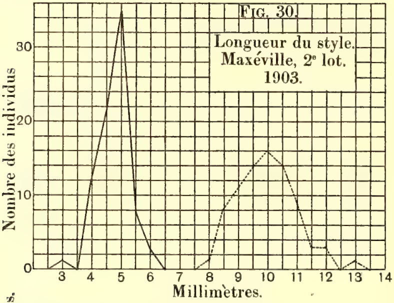


FIG. 30. Longueur du style. Maxéville, 2e lot. 1903.

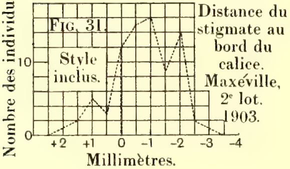


FIG. 31. Style inclus. Distance du stigmate au bord du calice. Maxéville, 2e lot. 1903.

Brévistylées —
Brévistémonées ----
Voyez Tabl. XII.

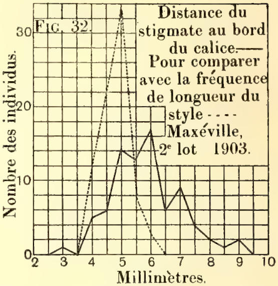


FIG. 32. Distance du stigmate au bord du calice.—— Pour comparer avec la fréquence de longueur du style ---- Maxéville, 2e lot 1903.

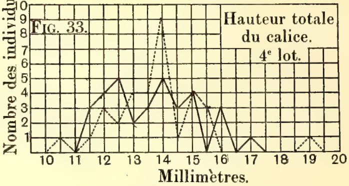


FIG. 33. Hauteur totale du calice. 4e lot.

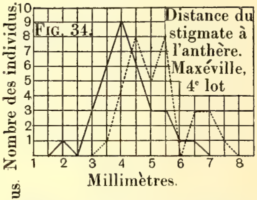


FIG. 34. Distance du stigmate à l'anthère. Maxéville, 4e lot

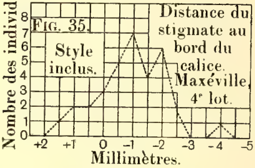


FIG. 35. Style inclus. Distance du stigmate au bord du calice. Maxéville, 4e lot.

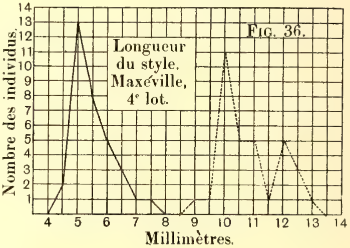
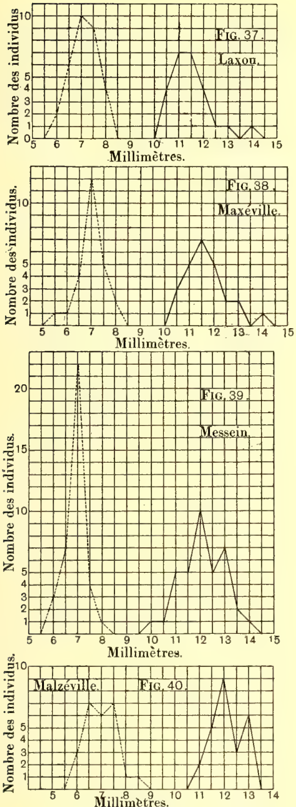
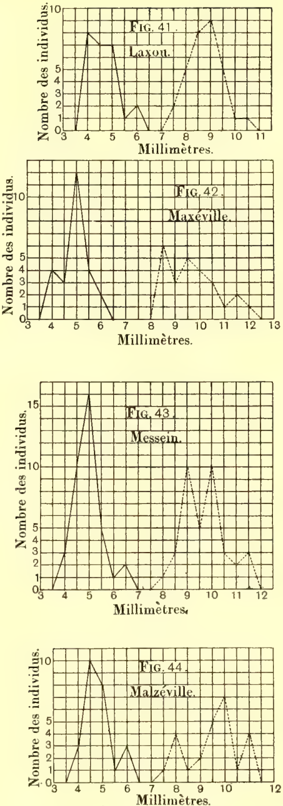


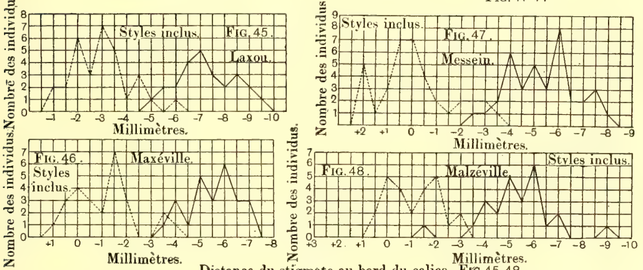
FIG. 36. Longueur du style. Maxéville, 4e lot.



Hauteur totale des étamines. Influence de la station. FIG. 37–40

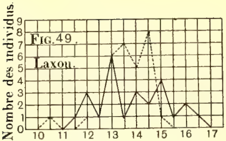


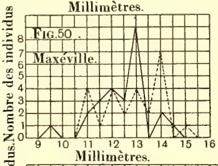
Longueur du style. Influence de la station. FIG. 41–44

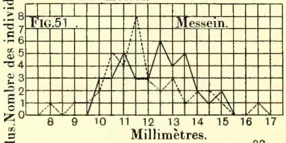


Distance du stigmate au bord du calice. FIG. 45–48

Influence de la station (voir Tableaux XV—XVIII). Plantes brévistémonées - - - - - -
Plantes brévistylées ——







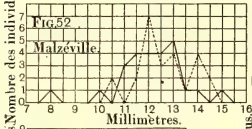
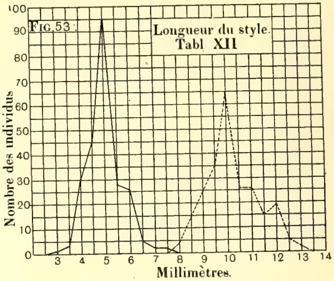
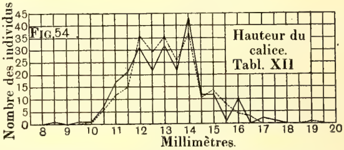
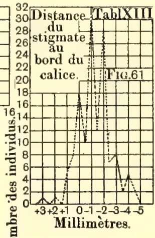


FIG. 49–52 Influence de la station. Hauteur totale du calice. Tabl XV—XVIII.







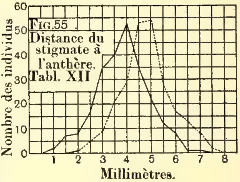
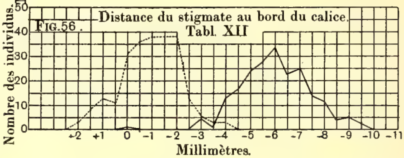
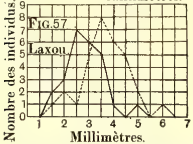
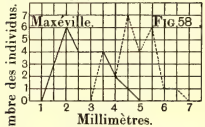
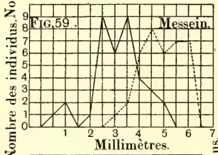


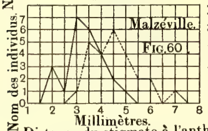
FIG. 53–56 Nombres totaux à Maxéville en 1903. Tabl. XII
FIG. 61–63 Nombres totaux à Maxéville en 1902. Tabl. XIII.

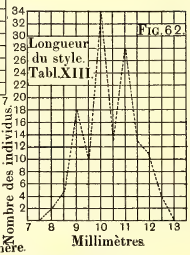


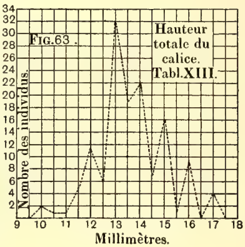












Distance du stigmate à l'anthère.
Influence de la station. Tabl. XV—XVIII. } = FIG. 57–60

Brévisténonées ----
Brévistylées ——

MISCELLANEA.

I. On the Correlation between Hair Colour and Eye Colour in Man.

It seems desirable in view of the recent discussions on the relationship between coat pigment and eye colour in certain mammals to ascertain whether there exists any constant relationship between these characters in the case of man. I have been able to collect the following tabled material, wherein far greater numbers have been reduced to permilles.

I. *Swedish Returns due to G. Retzius.*

Hair Colour.

		Blond	Braun	Schwarz	Roth	Totals
Eye Colour.	Hell ...	544	105	2	16	667
	Melist ...	191	87	4	6	288
	Braun ...	18	24	2	1	45
	Totals ...	753	216	8	23	1000

II. *Prussian Returns due to R. Virchow.*

Hair Colour.

		Blond	Braun	Schwarz	Brandroth	Totals
Eye Colour.	Blau ...	355	73	0	1	429
	Grau ...	242	78	5	1	326
	Braun ...	127	109	8	1	245
	Totals ...	724	260	13	3	1000

III. *Italian Returns due to R. Livi.*

Hair Colour.

		Blond	Braun	Schwarz	Roth	Totals
Eye Colour.	Hell ...	30	60	12	1	103
	Melist ...	27	132	45	2	206
	Braun ...	25	409	254	3	691
	Totals ...	82	601	311	6	1000

IV. *Germano-Jewish Returns due to R. Virchow.*

Hair Colour.

		Blond	Braun	Schwarz	Brandroth	Totals
Eye Colour.	Blau ...	114	82	0	1	197
	Grau ...	113	137	25	1	276
	Braun ...	100	333	92	2	527
	Totals ...	327	552	117	4	1000

V. *Baden Returns due to O. Ammon.*

Hair Colour.

		Blond	Braun	Schwarz	Roth	Totals
Eye Colour.	Hell ...	353	209	72	10	644
	Melist ...	46	112	66	5	229
	Braun ...	17	65	43	2	127
	Totals ...	416	386	181	17	1000

I have quoted the permille results in Tables I, III and V direct from Retzius and Fürst's *Anthropologia Suecica*, p. 155, and preserved their German terminology for describing hair and eye colours so that I may mark the fact that they consider the German classes to cover also the Italian-Swedish groupings. The original source of the Italian returns is R. Livi: *Antropometria militare*, Roma, 1898, and of the Baden, Otto Ammon: *Zur Anthropologie der Badenser*, 1899. Those for Prussian and Jewish children I have taken from the paper by Rudolf Virchow: *Farbe der Haare und der Augen der Schulkinder*, *Archiv für Anthropologie*, Bd. XVI. 1886, S. 468, etc. In II 4,127,744 children were classified, and in IV, 74,146. The correlations were determined from these numbers before reducing to permilles.

VI. *British Returns due to K. Pearson.*

Hair Colour.

		Fair	Brown	Dark	Red	Totals
Eye Colour.	Light ...	210	107	47	20	384
	Medium ...	117	158	113	15	403
	Dark ...	23	63	125	2	213
	Totals ...	350	328	285	37	1000

My data are from my observations on school children, in this case for boys only. I have put my categories 'Dark' and 'Jet Black' together as 'Dark' as the nearest equivalent to the continental 'Schwarz' possible under the circumstances. My three eye categories cannot be very different from the 'Hell,' 'Melist' and 'Braun' of Retzius' tables. Their exacter definitions will be found in *Biometrika*, Vol. III. p. 162. The importance of complete equivalence is, however, for our present purposes, not very great. We want to get the same number of reasonably definite groupings in each case. The six tables above each supply a 12-fold classification. From these tables the correlation between hair and eye colours was determined for me by Dr A. Lee using the method of mean square contingency,—a method which gives results independent of any scale order whatever*. We found

Correlation between Hair and Eye Colours.

Sweden	(Conscripts)	·2495
Prussia	(Schoolboys and Schoolgirls)	·2714
Italy	(Conscripts)	·3091
German Jews	(Schoolboys and Schoolgirls)	·3381
Baden	(Conscripts)	·3540
Great Britain	(Schoolboys)	·4203

Now these results seem to show that the correlation between hair and eye colours is by no means so close as has been hitherto supposed. Further it appears to be less in those districts which, whether light or dark, have a majority of one type. It is not improbable that the higher values in Baden and Great Britain are due to the effect of a greater mixture of local races, such local races not having interbred largely. In my opinion the results for the German Jews show that the population so classified is very far from being purely Semitic. If as I suspect the lesser values of the correlation occur in the *relatively* more homogeneous groups, then we might infer that increasing purity of race would mark a still slighter correlation between hair and eye pigment. In other words, if mankind originally consisted of several races each with a definite pure eye and pure hair colour, then the right statement is that the correlation between hair and eye colours was *interracially* unity or perfect, and *intraracially* zero. The point is of course one of terminology, provided the decreasing intraracial correlation with increasing racial purity be once established as a fact. But it is an important point of terminology, especially when pure races are crossed for hybridisation experiments. Is it correct to say that the correlation in white mice between eye pigment and coat colour is perfect? Since both characters are invariable, algebraically the correlation takes the indeterminate form 0/0. It is not unusual to call it 'perfect,' but I think the statement must be reconsidered in the light of the suggestion made in this note that possibly increasing racial purity marks decreasing correlation. The 'perfect' correlation in the case of the white mice is really a sub-conscious transfer of the idea, based on experience of white and grey mice, of an *interracial* correlation coefficient equal to unity. It is one of the many points where caution is needful in passing from the old conception of correlation in the sense of Cuvier as an association of two attributes to the modern biometric notion as a relation between deviations.

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* Pearson: "Mathematical Contributions to the Theory of Evolution. XIII. On the Theory of Contingency and its Relation to Association and Normal Correlation." *Drapers' Research Memoirs, Biometric Series, I.* (Dulau and Co., Soho Square, London.)

K. P.

II. On the Correlation between Age and the Colour of Hair and Eyes in Man*.

In recent work the resemblance of siblings in hair and eye colour has been used for measuring the intensity of collateral inheritance. In determining the correlation in pigmentation between siblings, allowance ought to be made for change of pigmentation with age supposing as in the case of man, we do not, as with greyhound puppies or thoroughbred yearlings, take the siblings at sensibly the same ages†. It is usually stated that eye and especially hair colour are modified by age, but hitherto no quantitative measure of the change seems to have been published. It is the object of the present paper to determine measures of this kind. Prussian school children as given by Rudolf Virchow ("Gesammtbericht über die von der deutschen anthropologischen Gesellschaft veranlassten Erhebungen über die Farbe der Haut, der Haare und der Augen der Schulkinder in Deutschland," *Archiv für Anthropologie*, Bd. XVI. 1886, S. 468–9) provided the following data. See Tables I and II. In these tables the so-called "andere Combinationen" were omitted as no ages were given; they are, however, very insignificant in total number. Using the method of mean square contingency, we have for children between 6 and 12 years of age:

Correlation of Age and Hair pigmentation = ·033.

Correlation of Age and Eye pigmentation = ·027.

TABLE I.

Age and Hair Colour, Prussian School Children.

Hair Colour.

Haare	Blonde	Braune	Schwarze	Brandrothe	Totals
Age *6—8*	409,830	129,225	5,172	1,622	545,849
8—10	1,565,036	555,287	25,736	5,405	2,151,464
10—12	488,938	190,729	8,866	2,208	690,741
12—14	131,883	55,023	2,443	602	189,951
Totals	2,595,687	930,264	42,217	9,837	3,578,005

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* I have put together the following results from Notes on this subject made by Dr Ginzo Uchida when working in my laboratory and placed by him at my disposal. K. P.

† The allowance is easy to make, if the correlation between pigmentation and age is known. See Pearson: *R. S. Proc.* Vol. 71, pp. 289—294.

TABLE II.

Age and Eye Colour, Prussian School Children.

Eye Colour.

Augen	Blaue	Graue	Braune	Totals
Age *6— 8*	227,223	178,014	140,612	545,849
8—10	946,576	692,249	512,639	2,151,464
10—12	292,756	229,221	168,764	690,741
12—14	74,277	66,445	49,229	189,951
Totals	1,540,832	1,165,929	871,244	3,578,005

The children above 14 have been omitted because few in number they come from a selected class, while the above compose the whole child population in the elementary schools.

It will be seen at once that the correlations are far lower than might have been anticipated. Indeed so low as to make no change of significance when we are dealing with the correlation of hair and eye colour in children, or with the degree of resemblance between siblings of 6 to 14 years of age*.

Virchow's data, however, combine the two sexes and it seemed desirable to consider the point for one sex only and possibly for a greater range of ages. Accordingly the following Tables were prepared from a portion of the sister-sister series of school data papers collected by Prof. Pearson.

TABLE III.

Age and Hair Colour, British Schoolgirls.

Hair Colour.

	Red	Fair	Brown	Dark	Jet Black	Totals
Age *4— 7*	2	16	6	3	0	27
7—10	10	86	79	20	0	195
10—13	16	165	160·5	73·5	4	419
13—16	19	136·5	189·5	91	3	439
16—19	6·5	71·5	90·5	55	1·5	225
Totals	53·5	475	525·5	242·5	8·5	1305

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* Pearson, Huxley Lecture. See *Biometrika*, Vol. III. pp. 149—150.

TABLE IV.

Age and Eye Colour, British Schoolgirls.

Eye Colour*.

	Light	Medium	Dark	Totals
Age *7—10*	73	74	41	192
10—13	147	180	85	412
13—16	120	214	96	430
16—19	64	99	57	220
Totals	404	571	279	1254

From these Tables by the method of mean square contingency we have:

Correlation between Age and Hair Colour = ·158.

Correlation between Age and Eye Colour = ·096.

Thus by dealing with one sex only and going on to 19 years of age, we see that the correlations while still not large are yet sensibly increased. If we may compare the German and English material, we should say that there is little change in hair or eye colour with children under 14; by this we mean, not enough to influence the determination of pigmentation resemblance of children of different ages. But after 14 there is even before 19 a more marked change, the correlations still, however, remaining low. This change is much more considerable in the case of hair than of eye colour, though sensible in both. Even thus the values of the collateral heredity coefficients, if we allowed for change of age, would hardly be influenced within the limits of their probable errors.

It would be interesting to trace the change in the correlation for one sex and race for later ages, but the material does not appear to be available. There is a table "showing the colour of eyes and hair of both sexes at all ages of English and Welsh origin" in the Final Report of the Anthropometric Committee of the British Association (1883)†. But the classification is different from that used in our data. Moreover the results are classified first according to eye colour, and in the case of eyes of a 'neutral' colour, the hair colour does not appear to be distinguished. Thus it is impossible to base a correlation table of hair colour at different ages on the B.A. data, and no satisfactory comparison can be made with our present results.

The only other material which is known to us is embodied in the *Sozialanthropologische Studien* of the late Dr W. Pfitzner of Strasburg, whose researches are in many respects both valuable and suggestive. But even where he deals with fairly numerous data‡, certain limitations soon appear. Thus for the period from 5 to 20 years he examined only 164 girls, and it seems impossible to determine a correlation from such numbers. Moreover his figures are exclusively based on observations made on the corpse. He ought therefore to have ascertained as a preliminary whether the proportions of different hair colours in the case of those who die early and in hospitals are the same as those of healthy children in the population at large. On the basis of our statistics this is improbable. A selective death rate in the matter of pigmentation, and peculiar selection of subjects, vitiates largely, we believe, returns based upon post-mortem room observations. All that has been done with Pfitzner's observations was to work out the Table for males from 0 to 75 years of age. This is given below.

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* Dr Uchida has omitted the ages 4 to 7 as of very small frequency. Tables for much larger numbers will be eventually published. Dr Uchida has not included the 'blue' schedules, principally infant schools, at all. Material is probably available for nearly 2,500 girls. K. P.

† *Report of the British Association*, 1883, pp. 278–9.

‡ Schwalbe's *Zeitschrift für Morphologie*, Bd. I. S. 372.

TABLE V.

Correlation of Age and Hair Colour. Males, Lower Elsass.

Hair Colour.

	Blond	Braun	Schwarz	Totals
Age *0—15*	384 {83·8}	74 {16·2}	0 { 0}	458
15—30	122 {35·8}	204 {59·8}	15 { 4·4}	341
30—45	119 {28·0}	261 {61·6}	44 {10·4}	424
45—60	120 {24·6}	292 {60·6}	75 {15·4}	487
60—75	58 {28·7}	105 {52·0}	39 {19·3}	202
Totals	803	936	173	1912

Using the method of mean square contingency we find:

Correlation between Age and Hair Colour = ·451.

Now if we were to trust this table we should have a very marked increase in black hair with increasing age, and this is the interpretation which Dr Pfitzner put upon results like this in his memoir. But a little consideration shows that this cannot be correct. Are we to say that there are no children with black hair in Lower Elsass, and that the 20 per cent. found among old persons is due to darkened pigmentation only? Prussia is lighter than Elsass but it contains 18 per 1000 of such children. We should have expected at least eight or nine black-haired children in Pfitzner's 458 under 15 years of age. Baden close to Elsass shows 18 per cent. of conscripts with black hair, while Pfitzner gives only 4·4 with black hair between 15 and 30! Pfitzner's results, if attributed to age-effect, seem quite incompatible with what is known of the normal population for Elsass. They are, however, quite comprehensible if there be a positive correlation between fairness and disease in childhood. Now this is exactly what our British school children show: *there is a correlation between health and darkness of hair colour.* Hence if we do not follow up individuals, noting their pigmentation at different ages, but simply correlate age of different individuals with hair colour, we are liable to exaggerate the correlation between age and pigmentation, and this will be especially the case, if we use hospital returns. Hence, it is probable that our neglect of a selective death rate, based upon the known correlation between general health and pigmentation, really emphasises the values found for correlation between pigmentation and age. Further, while it is probable that if we take adult life into account we should find this correlation increased—perhaps even to ·2 or ·25 —the value deduced from Pfitzner's observations of ·45 may be safely considered to mark in the first place a selective death rate, i.e. a correlation between fitness *in childhood* and dark pigmentation.

In conclusion it may not be without interest to exhibit the results for age, hair and eye colours of British Schoolgirls from 7 to 19 in a single table :

TABLE VI.

Correlation of Age with Hair and Eye Colours.

Hair Colour.

	Eyes	Red	Fair	Brown	Dark	Totals	
Age *7—10*	Light	4 {5·5}	52 {71·2}	17 {23·3}	0 { 0 }	73	192
	Medium	5 {6·4}	27 {34·6}	40 {51·3}	6 { 7·7}	78	
	Dark	1 {2·4}	6 {14·6}	20 {48·8}	14 {34·2}	41	
10—13	Light	6 {4·1}	92·5 {63·1}	43·5 {29·4}	5 { 3·4}	147	412
	Medium	10 {5·6}	57·5 {31·9}	82 {45·6}	30·5 {16·9}	180	
	Dark	0 {0 }	12 {14·1}	31 {36·5}	42 {47·1}	85	
13—16	Light	4 {3·3}	62 {51·7}	45·5 {37·9}	8·5 { 7·1}	120	430
	Medium	8·5 {4·0}	66·5 {31·1}	103 {48·1}	36 {16·8}	214	
	Dark	5 {5·2}	5·5 { 5·7}	38 {39·6}	47·5 {49·5}	96	
16—19	Light	3 {4·7}	31 {48·4}	21·5 {33·6}	8·5 {13·3}	64	220
	Medium	2 {2·0}	34 {34·3}	48 {48·5}	15 {15·2}	99	
	Dark	1·5 {2·6}	45 { 7·9}	18 {31·6}	33 {57·9}	57	
Totals	—	50 {4·2}	450·5 {58·9}	507·5 {31·5}	246 { 5·4}	1254	
All Ages	Light	17 {4·2}	237·5 {58·9}	127·5 {31·5}	22 { 5·4}	404	
	Medium	25·5 {4·5}	185 {32·4}	273 {47·8}	87·5 {15·3}	571	
	Dark	7·5 {2·7}	28 {10·0}	107 {38·4}	136·5 {48·9}	279	

The numbers in curled brackets give the percentages of each hair colour of girls of a given age having a given eye colour. Examining this table it would seem doubtful, having regard to the paucity of individuals dealt with, whether we can assert significant changes in the percentages of medium-eyed girls having fair or brown hair at different ages. Nor would it be wise to insist that the changes of percentages in red-haired girls with light or dark eyes are significant. Red-haired girls with medium eyes seem to become continuously fewer with age; light-eyed girls with fair hair become significantly fewer, and brown-haired girls with light eyes more numerous. Dark-eyed girls with fair or brown hair become significantly fewer and dark-eyed girls with dark hair become more numerous, and probably light-eyed girls with dark hair also. The medium-eyed girls with dark hair (except in infancy?) remain much the same in percentage. Thus except in the case of red-haired girls those with medium eye colour change least; the fair-haired girls with light eyes tend to become brown or even dark, and the dark-eyed girls with fair or brown hair to become dark-haired. How far these changes are influenced by a relative death rate still remains to be determined.

III. On the Contingency between Occupation in the Case of Fathers and Sons.

By EMILY PERRIN.

It is a problem of some interest to determine how far ancestral bent and how far environmental conditions influence a man in his choice of occupation in life. The discussion of this problem has become feasible since the introduction of the new method of contingency into the statistical treatment of related variables*. By this method all questions of continuity and of scale in the variables are dispensed with. We fall back on the simplest and most fundamental of ideas—a measurement of the deviation from independent probability in the case of the two variable characters. The coefficient of contingency measures the degree of association or dependence between any two series and becomes more and more nearly the coefficient of correlation as the material approaches normality. In Professor Pearson's memoir on Contingency he deals in Illustration D† with my first statistics of occupational contingency. These covered 775 cases of occupation for father and son classified into 14 groups; the material was extracted from the *Dictionary of National Biography.* I have since doubled the number of extracted cases, and taken an additional 1550 from *Who's Who.* I have kept the two materials quite distinct for comparative purposes. There are undoubtedly great differences in their character, although both sources of record are of course subject to selection, i.e. either father or son must have reached a moderate amount of distinction to be entered in either work. The following Tables give my material.

TABLE I.

Contingency between Occupations of Fathers and Sons (from Who's Who).

Occupation of Son.

Occupation of Father.	Army	Art	Teacher, Clerk, Civil Servant	Crafts	Divinity	Agriculture	Landownership	Law	Literature	Commerce	Medicine	Navy	Politics and Court	Scholarship and Science	Totals
Army	148	4	20	—	4	—	3	10	12	2	2	9	9	6	229
Art	—	38	2	—	2	—	1	1	7	—	3	1	—	8	63
Teacher, Clerk, Civil Servant	13	4	36	—	11	—	—	5	10	5	2	3	2	5	96
Crafts	—	2	—	1	1	—	—	—	—	—	—	—	—	—	4
Divinity ...	58	13	52	—	80	—	5	42	53	5	15	10	16	62	411
Agriculture ...	—	—	1	—	2	1	—	—	3	—	—	—	2	1	10
Landownership	42	5	17	—	15	—	20	24	13	10	10	15	30	14	215
Law	9	5	13	—	11	—	—	40	16	1	12	1	7	8	123
Literature ...	1	5	1	—	2	—	—	4	17	—	1	—	—	2	33
Commerce ...	4	8	6	—	11	—	—	19	12	33	3	1	2	17	116
Medicine ...	15	11	11	—	8	—	9	9	3	1	33	1	3	5	109
Navy	25	1	4	—	5	—	3	3	3	1	4	16	3	2	70
Politics & Court	3	—	3	—	—	—	—	1	3	1	—	—	15	—	26
Scholarship and Science	2	1	2	—	—	—	1	5	3	1	1	—	1	28	45
Totals	320	97	168	1	152	1	42	163	155	60	86	57	90	158	1550

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* "Mathematical Contributions to the Theory of Evolution. XIII. On the Theory of Contingency and its Relation to Association and Normal Correlation." By Karl Pearson. (Dulau & Co., London, 1904.)

† *Loc. cit.* p. 32 *et seq.*

TABLE II.

Contingency between Occupations of Fathers and Sons (from Dictionary of National Biography).

Occupation of Son.

Occupation of Father.	Army	Art	Teacher, Clerk, Civil Servant	Crafts	Divinity	Agriculture	Landownership	Law	Literature	Commerce	Medicine	Navy	Politics and Court	Scholarship and Science	Totals
Army	49	—	8	—	5	—	2	6	5	—	4	3	9	4	95
Art	2	105	1	1	3	—	—	2	4	—	—	1	1	2	122
Teacher, Clerk, Civil Servant	8	12	15	1	15	1	3	10	8	2	4	2	4	12	97
Crafts	1	21	1	14	7	—	—	2	14	5	3	—	—	18	86
Divinity ...	13	5	6	—	121	—	1	17	21	5	20	8	7	26	250
Agriculture ...	2	4	4	4	6	2	—	1	17	3	5	2	1	15	66
Landownership	23	3	7	—	14	8	8	22	9	1	10	12	37	15	169
Law	6	8	10	—	10	—	2	53	23	4	6	3	9	13	147
Literature ...	1	1	1	—	5	—	—	4	11	1	2	1	2	4	33
Commerce ...	16	31	9	2	35	—	—	16	31	39	9	3	12	38	241
Medicine ...	2	7	5	—	5	1	—	1	5	—	29	—	6	13	74
Navy	1	3	2	—	1	—	2	2	3	1	2	13	3	2	35
Politics & Court	13	—	3	—	4	—	2	9	3	—	2	3	34	1	74
Scholarship and Science	9	3	1	2	8	—	1	7	3	3	2	1	1	20	61
Totals	146	203	73	24	239	12	21	152	157	64	98	52	126	183	1550

It will be seen at once how the temporary official class which largely fills *Who's Who*, crowding Army, Navy and Civil Service columns, finds a much smaller place in the record of national importance. On the other hand Literature represented by 155 fathers and 33 sons in *Who's Who* contributes 157 fathers and 33 sons to a random sample of the same number from the *Dictionary*. The relative distinction of Literature is thus the same in the present and the past. Other single entries will be found on comparison of some suggestiveness, but I do not stay over them here.

Using Professor Pearson's notation I find:

For *Who's Who* (1550 cases):

Mean Square Contingency, $\phi^2 = 1{\cdot}285{,}868$,
Coefficient of Contingency, $C_1 = {\cdot}7500$.

For *Dictionary of National Biography* (1550 cases):

Mean Square Contingency, $\phi^2 = 1{\cdot}413{,}601$,
Coefficient of Contingency, $C_1 = {\cdot}7653$.

Professor Pearson for my first Table of 775 entries from the *Dictionary* gives*

Mean Square Contingency, $\phi^2 = 1{\cdot}299{,}206$,
Coefficient of Contingency, $C_1 = {\cdot}6275$.

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* *Loc. cit.* p. 34.

But $C_1 = \sqrt{\phi^2/(1+\phi^2)}$, and thus in the last case we ought to have $C_1 = \cdot 7517$, and not ·6275, which is due to an oversight in the arithmetic.

Thus we see that the coefficient of contingency whether found from a sample of 775 or one of 1550 from the *Dictionary* has sensibly the same value, and this value is identical with one found with the same classification and the same number of cases from such an entirely different source as the annual *Who's Who*. It seems clear that whether we take the present, or the long period of the past embraced by the *Dictionary*, the environmental influences which induce a man in this country to follow his father's occupation must have remained very steady. The coefficient of contingency for parental inheritance will be like the coefficient of correlation about ·5. I think, therefore, we may say that in the choice of a profession inherited taste counts for about $\frac{2}{3}$ and environmental conditions for about $\frac{1}{3}$. These numbers of 2 to 1 are somewhat less than the 3 to 1 given by Professor Pearson on the basis of the erroneous value ·6275 cited above. It would be extremely interesting to compare these results for an old country like Great Britain with those for a new country like America. *A priori* we should expect to find a greater freedom from environmental influences, a greater choice in the son, and so a nearer approach to a pure inheritance of taste.

IV. On a Convenient Means of Drawing Curves to Various Scales.

By G. UDNY YULE, Newmarch Lecturer in Statistics, University College, London.

Let an ordinary scale of equal parts, say inches, be engraved on the moving blade of a "clinograph," or adjustable set square, the zero point of the scale being at the lower end. If the blade be set at an angle θ to the horizontal, the vertical distances of the points 1, 2, 3... of the scale above a horizontal line XX drawn through the zero point, are evidently $\sin\theta$, $2\sin\theta$, $3\sin\theta$, etc. Hence if a curve be plotted to the base XX, with the scale maintained at this inclination, it will be drawn with a scale of which the unit is $\sin\theta$, where θ may take any value we please from 0° to 90°. The plotting proceeds in the ordinary straightforward way. Supposing two ordinates to be plotted are 8·95, 7·63, the clinograph is slipped along the T-square until the 8·95 of the scale falls over the proper vertical, when the point is pricked off; the clinograph is again shifted till the 7·63 of the scale comes over the second vertical and its value is similarly marked, and so on. A scale of variable inclination thus becomes, for plotting purposes, a scale with a continuously variable unit.

Such a scale is particularly convenient for plotting certain curves of given equation, e.g. the normal curves of errors,

$$y = y_0 e^{-\frac{x^2}{2\sigma^2}},$$

y_0 being the ordinate at the mean, and σ the standard deviation. In the ordinary way, the curve is plotted by the aid of tables giving the value of $e^{-\frac{1}{2}\xi^2}$, the most complete tables being those of Mr W. F. Sheppard (*Biometrika*, Vol. II. pp. 174—190). Intervals of, say, $\frac{1}{5}$th of the standard deviation are marked off along the base in either direction from the mean, ordinates erected at these points, and their magnitudes plotted from the tabular values multiplied by y_0. With the inclined scale this process may be considerably abbreviated.

To divide the base, the T-square or straight-edge is turned round at right angles* to the base, a length, say MS, equal to the standard deviation is plotted from the mean along XX, and the inclination of the scale is adjusted so that, when it moves along the T-square, the zero-point will pass over the mean M and the point 5 over the point S. The units of the scale will then give fifths of the standard deviation. Once the inclination has been adjusted, the T-square may be moved up or down if necessary to complete the plotting. The verticals are then drawn in, and the value of y_0 marked off on the central ordinate. The T-square being now placed parallel to the base, the scale and square are adjusted so that the zero point lies over the base and the point 10 over the top of y_0. The tabular values of $e^{-\frac{1}{2}\xi^2}$ then give the remaining ordinates directly from the scale readings.

---

* If the adjustment be made as described below, any inclination will do. Hence it is of no consequence if the two edges of the drawing board are not at right-angles.

Even the trouble of extracting or reading the tabular values may however be eliminated, if a special scale be engraved, in which the distances of the divisions from the left-extremity are proportional to the ordinates $e^{-\frac{1}{2}\xi^2}$. The inclination of the moving blade being once adjusted as above, the remaining ordinates are plotted direct from the divisions of the scale without interpolation.

As a matter of practice I have thought it best for the scales to be made, as in fig. 2, with the joint like an ordinary carpenter's rule, such a joint being stiff and wearing fairly well. The centre portion of each edge of the rule is bevelled for plotting, but the ends are left thick to prevent the rule slipping under the T-square or straight-edge. Four scales can be engraved on such a rule.

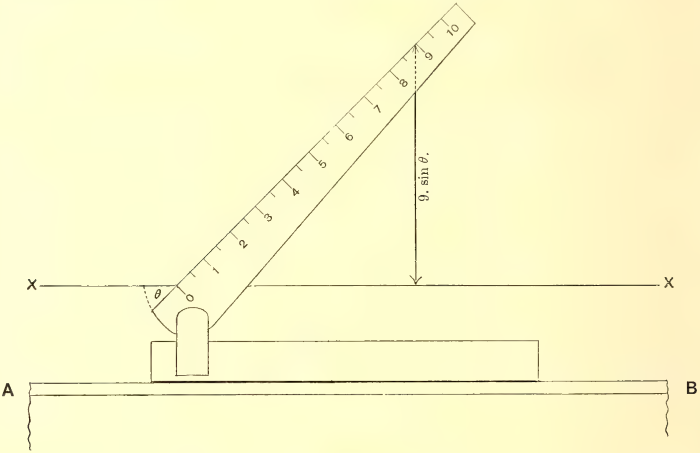

Fig. 1. **AB** is a straight-edge or T-square.

It is evident that the principle is applicable to a variety of curves, and I have had special scales engraved for plotting ellipses (the scale being given by equidistant ordinates in a quadrant of a circle), arcs of parabolas (such as are required in drawing parabolic girders, bending moment curves, etc.), curves of sines or cosines, and the normal curve of errors. The scales were made for me by A. G. Thornton, King Street West, Manchester. For statistical work, three plain scales of different units and divisions and a normal-curve scale form a convenient set. With the plain scales, curves of any sort are readily plotted with any desired ratio of length to breadth, e.g. for reproduction on a given page or lantern slide.

The idea of using a scale at a variable inclination is such a simple one, that it scarcely seems possible it can be novel, though new to me. Many ideas of considerable antiquity, e.g. "Gunter's Lines," come extremely close to it. The advantage, however, of the inclined scale, used direct on the drawing board, over the Gunter's lines (scales divided on lines passing through the pivot of the carpenter's rule), is very considerable in point of time, the use of dividers being avoided altogether.

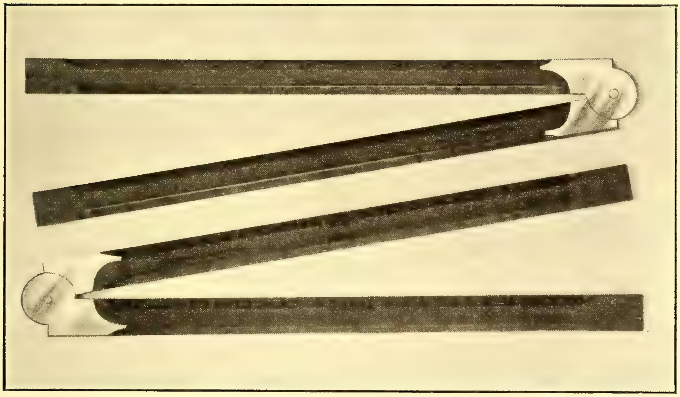

FIG. 2.

V. Albinism in Sicily—A Correction.

The abstract of *Biometrika*, Vol. III. Pt. I. contains this passage: "W. F. R. Weldon shows that the data from Sicily provided by Arcoleo are not in accordance with Mendelianism nor with the theory of gametic purity." These words fairly give the purport of the article appearing at p. 107 of that number, over Professor Weldon's initials.

On looking into the matter I find that the more serious of the two considerations Professor Weldon adduces, namely, the production of two pigmented children as well as three albinos by two *albino* parents, rests on a mistake. His acquaintance with Arcoleo's work is derived from *Archivio per l' Antropologia*, I. 1871, but he apparently failed to notice that this was not an original communication. The original, from which the *Archivio* copied a part only, appears in *Gazeta Clinica* dello Spedale Civico di Palermo, F. II. (1871). Here Arcoleo states explicitly that he never met with any case of an albino child being born to an albino parent. The following passages give his words*.

"Passando all' albinismo della specie umana, si chiede: è anch' esso ereditario? Per dirsi ereditario un vizio o un morbo, bisogna che si ripeta nei discendenti nel modo onde esiste negli ascendenti. Eppure in 24 famiglie da me esaminate, in nessuna è preesistito un esempio di tal genere, nè nei 24 figli procreati dai cinque albini coniugati ve ne ha uno solo che richiami il tipo albino del padre o della madre. Parrebbe adunque che l' albinismo nella specie umana non fosse affatto ereditario, &c."

* Pp. 12—13 of reprint. I cannot give the original pagination.

Again: "Non essendo ancora dimostrato l' albinismo ereditario nell' uomo, si dimanderebbe sempre; quale è la causa prossima che lo ingenera?"

Therefore the parents of family No. 7 were not as Professor Weldon states, both albinos, but *both pigmented.* The words which misled him, "Gli antenati furono tutti bianchissimi" plainly refer to "the extraordinary fairness of many blonde persons, who were still slightly pigmented," a phenomenon witnessed by Professor Weldon himself in Sicily.

On the other hand this correction somewhat increases the discrepancy from Mendelian expectation to which Professor Weldon also calls attention. The families from supposed *DR* parents, as corrected, contained 86 pigmented, and 52 albinos, the expectation being 103·5 and 34·5, a notable deficiency of normals.

For several reasons I suspect that these numbers must be taxed before any deduction can be drawn with great confidence from the deficiency of normals; but it is by no means improbable that the deficiency does indicate some real complication, which indeed may on other grounds be already apprehended.

When I had occasion to refer to albinism in Man I wrote as follows (*P. Z. S.*, 1903, II. p. 77) "Naturally we may inquire whether albinism in Man is not a similar recessive. Castle has given evidence pointing in this direction. The occurrence of albinism in the families of first cousins (see Day, Seligmann, &c.) is consistent with this view; but there are a few recorded cases of the occurrence of albinos in the offspring of albinos breeding with normal parents, where the hypothesis that the normal parent was *DR* is not at all easily admissible. No case of the union of two human albinos is known to me. The matter cannot here be further discussed, and the reader must refer to the literature, the most important paper being that of Cornaz."

These words seem to me to express very clearly the doubt I then felt (1903). It was surprising to find them transformed by Professor Weldon into the statement that "the suggestion [that albinism in Man has a Mendelian behaviour] is considered probable by Bateson." Nevertheless after further experience, and especially after study of Arcoleo's paper (previously known to me by title only) with its record of 5 families bred within the 2nd canonical degree of relationship, I now lean with some decision towards the view that albinism in Man will be shown to have a Mendelian inheritance, possibly, as I said above, with a complication.

W. BATESON.

25 *November*, 1904.

[I think Dr Arcoleo's memoir hardly bears out in one respect the interpretation Mr Bateson puts upon it. I am not clear what Dr Arcoleo means by the words cited by Mr Bateson at the bottom of p. 471. The emphasis may be on *nel modo* and *di tal genere.* They may refer to the special type and intensity of the albinism, for example in regard to defective vision and nystagmus. But I do not think it possible to interpret them in the sense of Mr Bateson: "Here Arcoleo states explicitly that he never met with any case of an albino child being born to an albino parent." Dr Arcoleo states explicitly that the mother of the four albinos in Family No. 6 was "una albina di belle forme," and the union (within the second canonical degree) arose from the desire on the part of the Cav. N. N. to have an albino daughter like her. If the *Cavaliere* was *DD* then the case is in favour of Professor Weldon; if he was *DR*, then the result in this family, 4 albinotic and 7 pigmented offspring, was reasonably in accordance with the Mendelian expectation, which is 5 5 ± 1. K. P.]

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Abstract of Articles in Biometrika, Vol. III. Parts II. and III. March—July, 1904.

(1) This double number contains two memoirs dealing with the selection of small variations. In the first Dr H. E. Crampton presents us with the first of his studies on variation and elimination in *Philosamia cynthia.* He demonstrates that elimination actually does occur during pupal existence as well as at the time of metamorphosis. The individuals who successfully survive these conditions are in some respects structurally different and on the whole less variable than those that do not. Natural selection thus certainly exists for the material under consideration. According to Dr Crampton the selection must be considered as *indirect,* i.e. due to correlation, for it can hardly be considered, for example, that stouter antennae can be of service to the pupa, when it does not use them, and yet the less stout antennae are eliminated in the pupal stage. In short the test of fitness or unfitness has reference to the physiological coordination among the constituent elements of the whole organism, and does not necessarily depend upon the use advantage at a particular stage.

In the second paper W. F. R. Weldon deals with the problem as to whether small variations in the form of the shell spiral in a race of *Clausilia* exhibit sensible selection between the young and the adult stage. A previous investigation into another race of *Clausilia* had afforded strong evidence of such periodic selection. Contrary to his experience in the case of *C. laminata,* no evidence of selective elimination could be discovered in the shell characters investigated in *C. itala.* We are therefore compelled to conclude (i) either that the young were collected after the main selection had taken place or (ii) that the environment is so favourable that at present no selection is taking place. Taken in conjunction with Crampton's results and the earlier work on *C. laminata* we must assert that while selection of small variations certainly does take place in very different forms of life, it is not universally occurring in all species under every environment in every period.

(2) A second paper, On the Laws of Inheritance in Man, deals with the inheritance of the mental and moral characters and its relation to that of the physical. The method of the paper is the comparison of the intensity of likeness in mental and in physical characters in the case of brethren. The general conclusion is that the mental, moral and physical characters are inherited in sensibly the same manner. Whatever influence environment may have it does not serve to intensify the moral and mental resemblance of brethren beyond the physical resemblance. Nor do brethren in the case of physical characters less subject to environmental influence show less resemblance than in the case of physical characters which can be influenced by food and training. The bearing of this result on the problem of national degeneracy is emphasised.

(3) W. R. Macdonell publishes the first memoir dealing with any considerable number of English skulls. The material, covering between 300 and 400 crania, with a high degree of probability formed the contents of a London City plague pit of 1665. The measurements, 42 in number, are given and their biometric constants compared with those of allied European and unallied races. Normal and abnormal crania are illustrated by fifty plates; it is hoped that the photographs of special crania will serve as the beginning of a series to which reference may be made in describing abnormalities in future memoirs. The general results indicate that this series differs very widely from the German and French series, and from the English head as described by various modern writers. That the series, however, is typical at least of the 17th century Londoner is proved by comparison with a second series of London skulls. It is shown by some appended statistics that the most comparable data are those of the Long Barrow race

[P. T. O.

scattered up and down Europe. It would appear probable that that race has contributed largely to the London, if not to the whole English population, a conclusion which should serve to modify a good deal of historical and anthropological opinion.

(4) The fourth memoir, a cooperative paper, deals with the colour inheritance of Greyhounds. The material consisted partly of schedules filled in by breeders, partly of data extracted from the Greyhound Stud-books. It was found quite impossible to neglect ancestral influence and no means of fitting the material into any Mendelian formula was apparent. The parental and grandparental correlations have sensibly the same intensity as for man and horse, and we may therefore reasonably suppose them to fit the geometrical law of decreasing intensity (*Ancestral Law*). The fraternal correlations for the data drawn from the stud-books agree well with the results for man and Basset Hound, but those drawn from the schedules are much higher, comparable only with the fraternal correlations in the case of the thoroughbred horse. A number of special investigations were made to elucidate this difference, but the only solution that can be offered seems to be that the coat colours entered on the schedules were observed at a very early stage, and that the litter at this stage is more uniform than later, possibly after the shedding of the first coat. The Greyhound may be a confirmed "heterozygote," but if so the memoir seems to show that any population of this character in man, horse, or dog obeys closely the ancestral law of decreasing correlation.

(5) In the *Miscellanea* will be found an elementary proof of Sheppard's formulae for correcting raw moments, and also approximate formulae for passing from the ordinates of frequency curves to the adjacent areas or sub-frequencies.

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